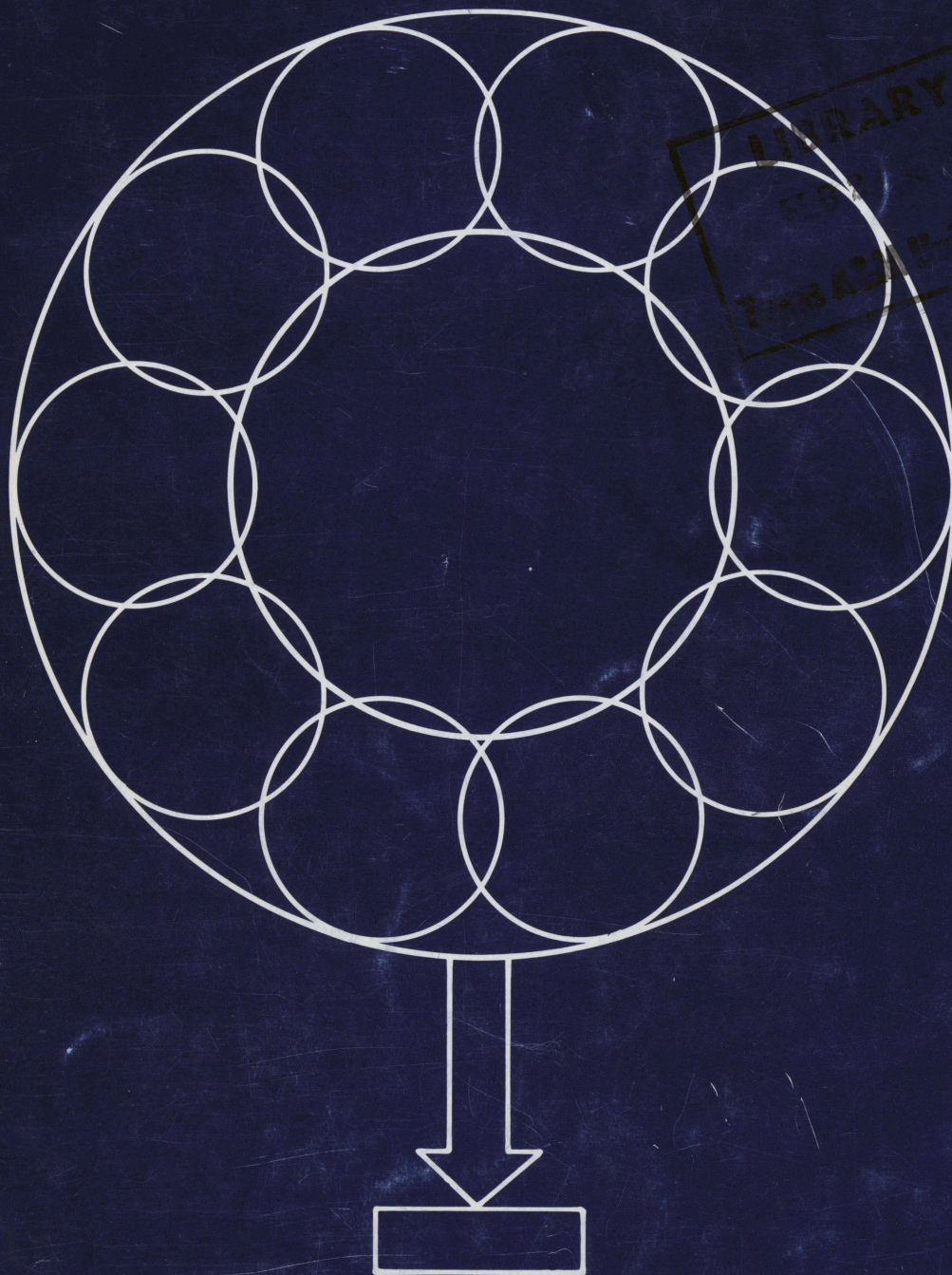
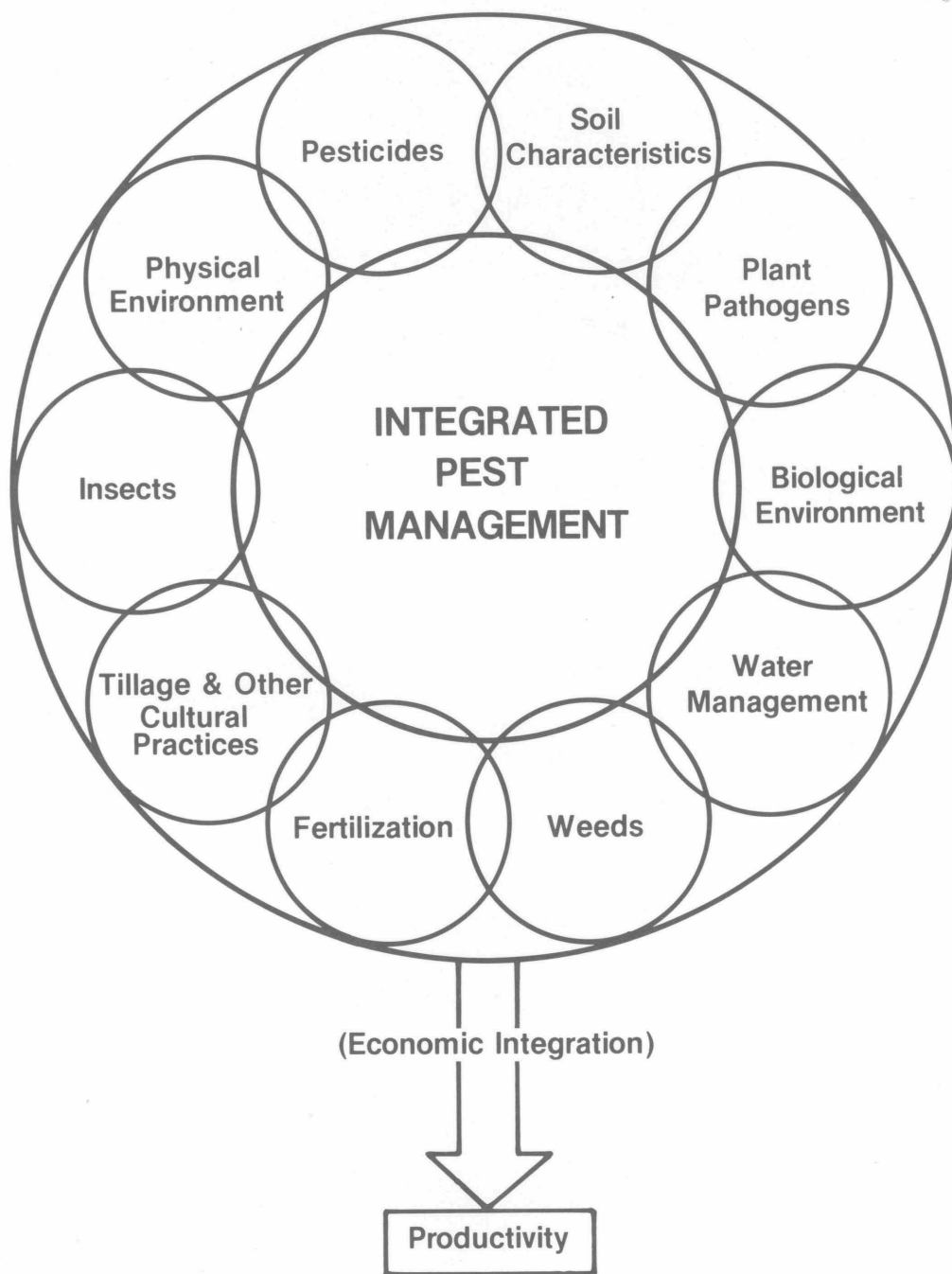


no. 1378

STATEWIDE PEST MANAGEMENT PLAN FOR TEXAS



Texas Agricultural Extension Service/Texas Agricultural Experiment Station
The Texas A&M University System, College Station, Texas



A STATEWIDE PEST MANAGEMENT PLAN FOR TEXAS

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Introduction

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High Plains and Adjacent Rolling Plains Counties Pest Management Plan

D.R. Rummel (Chairman), J.R. Abernathy, T.L. Archer, J.R. Cate, B.C. Gunter, E.B. Hudspeth, J.W. Johnson, J.F. Leser, G.L. Teetes, B. Ott, C.D. Patrick, C.C. Orr, C.E. Rogers, J.R. Supak, R.G. Thompson, P.W. Treptow, G.B. Cronholm, M.E. Rice and W.C. Jany

Rolling Plains Pest Management Plan

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Trans-Pecos Pest Management Plan

C.W. Neeb (Chairman), J.R. Cate, G.D. Condra, D.G. Foster, J. Gannaway, J.D. Hanna, B.A. Lee, K.E. Lindsey, J. Moore, R.D. Siegmund, J.D. Stone, H.W. Kaufman, G.P. Watterson and L.L. New

Blacklands, West Cross Timbers and Hill Country Pest Management Plan

C.E. Hoelscher (Chairman), G.F. Arkin, L.S. Bird, J.E. Burleson, W.E. Buxkemper, Allen Dobson, M.K. Harris, R.W. Hoermann, J.D. Johnson, T.A. Lee, S.D. Lyda, G.R. McEachern, F.R. Miller, G.C. Moore, F.W. Parker, M.F. Schuster, D.H. Smith, J.W. Smith, Jr., J.B. Storey, B.W. Swaim, G.L. Teetes, L.D. Tripp, H.W. Turney, J.K. Walker and T.L. Woodward

East Texas Pest Management Plan

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Central Texas River Bottoms Pest Management Plan

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Upper Gulf Coast Pest Management Plan

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Lower Gulf Coast and Winter Garden Pest Management Plan

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Rio Grande Valley Pest Management Plan

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BUGNET — A Computerized Pest Management Information Delivery System in Texas

J.A. Jackman (Chairman), J.L. Hensen, G.L. Curry and P.J. Sharpe

The Role of the Private Consultant

R.E. Frisbie

Texas Agricultural Experiment Station Long-Range Plan

R.E. Frisbie

Texas Agricultural Extension Service Program Thrusts for the 1980's

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Preface

The Statewide Pest Management Plan is designed to serve as a tool for guiding major integrated pest management (IPM) programs in Texas. This plan was developed by interdisciplinary scientific groups from the Texas Agricultural Experiment Station and the Texas Agricultural Extension Service of The Texas A&M University System, in cooperation with the USDA and the Texas Department of Agriculture, in response to a request from the agricultural leadership in Texas. The Statewide Pest Management Plan seeks to organize, in a comprehensive way, the future direction for IPM programs within the state. The plan includes IPM systems for cotton, sorghum, corn, peanuts, rice, riceland mosquitoes, soybeans, citrus, pecans, timber, small grains, alfalfa, sunflowers and forage grass. Systems are being developed for the management of urban pests and livestock pests. And, it is anticipated that a program will be developed for fruit trees. The goals of the Statewide Pest Management Plan are to increase net profit to Texas producers by reducing production costs, and to minimize the possibility of environmental disruption by the intelligent

use of pesticides. The key to achieving these goals is a systems approach that analyzes all methods of minimizing losses caused by noxious pests.

The Texas Agricultural Experiment Station Long-Range Research Plan and the Texas Agricultural Extension Service Program Thrusts for the 1980's have been considered in the development of this plan. Special sections highlight and review these plans.

The farmers of Texas and their commodity associations (Texas Pest Management Association, Texas Association of Cotton Producer Organizations, Grain Sorghum Producers Board, Peanut Producers Board, Texas Pecan Producers Association, Texas Citrus Mutual, American Soybean Association-Texas Chapter, and the American Rice Growers Cooperative) have been extremely helpful in the development and review of this plan.

The Texas Pest Management Association requested the writing of A Statewide Pest Management Plan for Texas. This plan is dedicated to the Association for its support in advancing IPM in Texas.

Table of Contents

	Page
Introduction	10
High Plains and Adjacent Rolling Plains	16
Rolling Plains	20
Trans-Pecos	24
Blacklands, West Cross Timbers and Hill Country	34
East Texas	40
Central Texas River Bottoms	44
Upper Gulf Coast	48
Lower Gulf Coast and Winter Garden	60
Rio Grande Valley	68
BUGNET, A Computerized Information Delivery System in Texas	72
The Role of the Private Consultant	76
Texas Agricultural Experiment Station Long-Range Plan	78
Texas Agricultural Extension Service Program Thrusts for the 1980's	82

INTRODUCTION

In a time when drastically increased production costs and decreased farm prices are cutting sharply into farm profits, Texas remains the nation's leading cotton and sorghum producer. The total economic impact of agriculture and agribusiness in Texas is estimated at \$33.7 billion. Some of the greatest limiting factors in the production of major crops in Texas are insects, weeds and diseases. For example, insects causes losses of nearly \$100 million annually to the state's cotton producers, while insecticide treatments increase production costs another \$20 million. Losses to sorghum producers of approximately \$40 million a year are attributable to major insect and mite pests. Similar losses are caused by weeds and plant pathogens. Efficient and effective management systems have been and are currently being developed to economically manage major pest species with a minimum of environmental disruption. Recently, intensive research and pilot Extension programs have been directed at developing management systems to minimize pest losses on major crops, especially cotton, sorghum and peanuts. An all-out effort has been underway to develop and test integrated pest management (IPM) technology by the Texas Agricultural Experiment Station and USDA/SEA-AR. The Texas Department of Agriculture and USDA-APHIS have supported these programs through boll weevil suppression programs and regulatory activities.

Quite naturally, the focus has been on cotton because it is a major consumer of pesticide in Texas. Classic cases of overuse or misuse of insecticides occurred in cotton in the mid-to-late 1960's. Prior to that time, certain key insects, primarily the boll weevil and tobacco budworm, had developed resistance to some classes of insecticides. The resistance of the tobacco budworm to all known insecticides occurred in the late 1960's, causing widespread alarm across cotton producing areas of the state. The tobacco budworm and a similar species, the cotton bollworm, extensively damaged cotton in the Lower Rio Grande Valley of Texas, and caused a total industry collapse in northeastern Mexico just south of the Rio Grande River. As the resistant tobacco budworm spread into other cotton producing areas of the state, a well organized research and Extension effort was begun to find an economic and ecological solution. As a result of this crisis, a revolutionary method of modern cotton production was developed. New cotton varieties were developed and produced. These varieties required far less time to fruit and reach maturity than convention-

ally grown, long season cotton varieties. The new varieties were termed "short season." Most of them were TAMCOT varieties, although several other commercial varieties have been released. The short season cotton management system emphasized uniform planting, careful monitoring (scouting) of the fields to determine the need for and precise timing of insecticide applications, and early harvest and thorough post-harvest stalk destruction to reduce food reservoirs for overwintering insect species.

The catastrophe that occurred in cotton in the late 1960's almost occurred in sorghum in 1974-75 as the greenbug became resistant to most insecticides. Fortunately, greenbug resistant sorghum hybrids were available and were planted before major damage was sustained. A system also was developed to integrate the management of sorghum insect pests with cotton pest management in order to minimize destruction of beneficial insects that live in sorghum and eventually move into cotton. Insect control in these two crops must be coordinated in order to deal with their interacting relationships. This management strategy is equally important for weed and disease control. Crop rotation still plays a major role in weed control and in the suppression of cotton root rot.

Sorghum has replaced cotton as the state's major consumer of insecticide, primarily because of the sorghum midge. As with the greenbug, an all-out effort is underway to develop hybrids resistant to the sorghum midge.

In 1972 and 1973, pilot programs were begun to field validate cotton and sorghum integrated pest management systems, and to introduce these systems to Texas farmers. The Grain Sorghum Producers Board and regional associations of the Texas Association of Cotton Producer Organizations underwrote and strongly supported this activity. These pilot programs were conducted by the Texas Agricultural Extension Service. Extension agents-entomology (PM) worked with county and area Extension staff members to demonstrate the need for pest management through a broad-based educational program. Extension agents-entomology (PM) hired, trained and supervised insect field scouts who systematically inspected farm crops for insects and their damage, beneficial insects and the progress of plant fruiting. The field scouting demonstration encompassed 6,000 to 15,000 crop acres within the 2- to 3-county areas. Participating farmers paid for 50 percent of scout costs in the 1972 program, and by 1974 they were paying 100

percent of all costs. Extension agents-entomology (PM) worked individually with farmers to assist them in making pest management decisions based on accurate field records. In conjunction with the scouting activity, a major production scheme was also demonstrated in the pilot pest management programs. The short season cotton system was introduced by way of demonstration, and once again, the interrelationship between grain sorghum management and cotton management was stressed. The eyes and hopes of Texas farmers were focused sharply on these pilot programs, and their results were fortunately quick in coming.

The profits to be made from IPM are well documented. The Texas Agricultural Extension Service and Texas Agricultural Experiment Station have developed insect pest management programs for the major cotton, sorghum and peanut production areas of the state. The programs are proven profit makers in area-wide and individual farm demonstrations. Following are examples of the profits that may be made through the use of the best pest management practices.

1) **High Plains:** An area-wide boll weevil suppression program, by keeping the weevil out of the High Plains, prevented the use in this region of between 8 and 20 million pounds of insecticide annually, and saved between 75,000 and 125,000 bales of cotton and \$12 to \$20 million in total production costs that otherwise would have been lost.

A pilot pest management program for grain sorghum in Hale County showed that much sorghum was being sprayed needlessly for greenbug control. Amounts of insecticides applied per acre and to the total acreage of sorghum have been reduced. Greenbug resistant hybrids that require little spraying were introduced in 1975 and 1976.

Greenbug resistant sorghum hybrids are grown on about 50 percent of the acreage in Texas. These hybrids were developed, for the most part, from germplasm from the Texas Agricultural Experiment Station. Conservative estimates place the value of greenbug resistant sorghums at \$10 million per year in insecticide cost savings alone. This does not include savings from reduced yield losses. Equal or greater potential exists in the development of sorghum midge resistant sorghums. Their value may be \$10 million per year during normal years, and \$50 million per year during severe midge damage years in insecticide cost savings and reduction of yield losses.

2) **Rolling Plains:** The Rolling Plains region contributes significantly to the state's cotton production. An IPM program centering around the boll weevil, the key economic pest, has been developed. Area-wide delayed uniform planting has protected cotton from spring emerging boll weevil populations. This cultural technique, along with intensive scouting and survey programs and fall boll weevil control programs, has increased yields and net returns to farmers. Reduced insecticide use has increased net profits by an estimated \$3.4 to \$5.5 million. The number of harvested acres has increased 51 percent from 703,700 to 1,051,250, partially because of this IPM strategy. Delayed uniform planting made it

possible for cotton producers to use areas previously abandoned because of heavy boll weevil infestations.

3) **Upper Gulf Coast:** An integrated insect control program developed on the farms of the Texas Department of Corrections has increased cotton yields almost 50 percent, decreased insecticide use by 50 percent and increased net returns per acre by approximately \$35. It is estimated that using the program on the more than 200,000 acres in this production area could increase cotton output by 27,000 bales annually, reduce the amount of insecticides applied by 1.4 million pounds and increase producer profits by \$5.4 million.

Pesticide savings have increased net returns in a Fort Bend County pecan IPM program. Insecticide savings alone increased net profit \$1,625 for a 50-acre pecan orchard.

4) **Texas Coastal Bend:** Cotton yields increased dramatically in this region with the introduction of multiple adversity resistant (MAR) short season cotton varieties (TAMCOT) in the early 1970's. From 1974 to 1979 cotton yields averaged 494 pounds of lint per acre. From 1968 to 1973, before the new varieties came into use, yields averaged 269 pounds per acre. The use of new disease resistant, cold tolerant, short season varieties, along with the adoption of IPM strategies, increased gross returns in the Coastal Bend by an estimated \$29 million. The pest management program in San Patricio, Nueces and Kleberg Counties, begun in 1976, has shown a consistent increase in net profits of \$42.60 per acre (1976 to 1979) as a result of reduced insecticide costs and improved yields through total crop management. If short season, integrated pest management were adopted throughout the Coastal Bend, net profits could be increased by an additional \$11.0 million.

5) **Winter Garden:** A demonstration with the new short season TAMCOT cotton varieties, conducted in 1974 in Frio County, indicated that these cottons may be grown in an integrated system with far greater profits than conventional varieties. The TAMCOT cotton received only 25 pounds of nitrogen fertilizer per acre, two early season insecticide treatments and one irrigation. The old varieties received 100 to 200 pounds of nitrogen fertilizer per acre, six to ten insecticide treatments and two or more irrigations. The TAMCOT cotton grown in the integrated system demonstration produced 800 pounds of lint per acre and approximately \$100 per acre more profit than the average received by the farmers in this area. As a result of this study, greater emphasis has been placed on short season, low economic input production.

6) **Lower Rio Grande Valley:** Farmers participating in the Texas Cotton Pest Management Program in the Lower Rio Grande Valley increased their net profits by \$55.31, \$15.72 and \$23.30 per acre in 1973, 1974 and 1976, respectively. Similar increases were observed for 1977 through 1979. If pest management practices were implemented on 250,000 acres throughout the valley, increased profits might well

reach \$9 million annually. Recently, short season varieties produced in narrow row systems have increased yields by an average of 130 pounds per acre, while reducing production costs.

- 7) **Trans-Pecos:** The Texas Cotton Pest Management Program in Pecos and Reeves counties increased producer profits by \$30.59 and \$54.13 per acre in 1973 and 1974, respectively. Despite inflated 1974 production costs and depressed market prices (\$0.40 per lb.), participating producers realized a market profit of \$3.60 per acre. Those not participating lost an estimated \$57.73 per acre. Results of the Trans-Pecos program strongly indicate the need for good pest management as an integral part of the total cotton production system.

High water and insecticide costs have caused a drastic decline in cotton production in the Pecos Valley over the last 10 years. But thanks to Econocot, an economic and interdisciplinary cotton production system introduced in 1978, a resurgence in cotton production has been taking place (Coyonosa). Farmers are returning to the Pecos Valley under the Econocot system.

- 8) **Blacklands:** The pest management program in Hill and Ellis counties has proven to be economically successful. Profits of participating producers were increased by \$17.95, \$18.90 and \$95.45 per acre in 1973, 1974 and 1975, respectively. These increases represent a high rate of return per dollar invested in this area of relatively low production costs and returns. Based on 1980 estimates of planted cotton acreage, profits could be increased by nearly \$14 million throughout the Blacklands if the pest management program were followed.
- 9) **West Cross Timbers:** In 1974, a multidisciplinary (insects, weeds and diseases) pilot peanut pest management program conducted in Comanche County increased net profits by \$15.90 and \$24.42 per acre for irrigated and dryland peanuts, respectively. In 1975, increased net profits reached \$64.00 and \$38.00 for the two respective cultures. The peanut program is an excellent example of the importance of an interdisciplinary approach to pest management.

Producers participating in the Rio Grande Valley, Blacklands and Trans-Pecos cotton pest management programs in 1973 and 1974 realized more than \$2 million in increased net profits on 35,000 acres of cotton. Total program costs (from USDA cooperative grant funds and producer scout costs) were \$322,415. This represents a return of \$6.39 for every dollar invested, and strongly supports the economic benefits of this program to agriculture and society. A similar economic study was conducted on the expanded 1976 cotton pest management program. Average increases in estimated net profit amounted to \$59.10 per acre over 100,000 acres in the program. The increase in total net profit was estimated at \$5.9 million. State, federal and farmer contributions totaled \$719,934, for a return of \$8.19 for every dollar invested. Similar increases were seen in 1977, 1978 and 1979. Tax revenues and benefits to society generated from

increased net profits more than offset state and federal government investments.

The results of these programs have also caught the interest and support of environmentally concerned citizens. These citizens see integrated pest management as a way to minimize the misuse of pesticides and reduce the amount entering the rivers, reservoirs and coastal waters of Texas. A common ground has been struck between agricultural production and environmental protection.

The close working relationship between The Texas A&M University System and the Texas Association of Cotton Producer Organizations (TACPO) has led to major inroads in the development and implementation of IPM in Texas. In 1974, TACPO requested that The Texas A&M University System develop a multi-regional IPM program plan to provide a working document for statewide direction. Teams of scientists from The Texas A&M University System, USDA and Texas Department of Agriculture developed subplans for the nine major agricultural producing areas in the state (High Plains and adjacent Rolling Plains, Rolling Plains, Trans-Pecos, Blacklands, Central Texas River Bottoms, Upper Gulf Coast, Lower Gulf Coast and Winter Garden, East Texas and the Lower Rio Grande Valley). A special section of the plan detailed the TAMU-BUGNET computerized information and delivery system. The emphasis of the 1974 Statewide Pest Management Plan was, for the most part, on cotton. Each subsection of the plan included a careful study of the major pest species attacking cotton, a review of current research, future needs for research, needs for Extension delivery systems, regulatory needs and, finally, an estimate of program costs. The plan has served as a guideline since 1974. Using the plan as a base, the Texas Pest Management Program has expanded in an orderly fashion based on solid economic, environmental and sociological data from a pilot phase (1972 to 1974) of five programs, to the second phase (1975 to 1976) of 20 programs, and on to a third phase that presently includes 26 programs in 54 counties. It is extremely important that additional programs in research and Extension be developed to support this proven program.

The following revised plan includes additional crops and a variety of needed disciplines that should be incorporated in a working plan for the major agricultural areas of the state. The goals are to increase net profit to Texas farmers by reducing production costs, and to minimize the possibility of environmental disruption by the intelligent use of pesticides. These goals can be achieved through using a systems approach that analyzes all methods of minimizing losses caused by noxious pests.

Recommendations

The following revised plan is a compilation of ten subplans developed by regional teams of research and Extension entomologists, plant pathologists, weed scientists, agronomists, agricultural economists, agricultural engineers and plant breeders. Although the

plan centers around cotton, sorghum, corn and peanuts, rice and riceland mosquitoes, soybeans, citrus, pecans, timber, small grains, sunflowers and forage grass also are considered. This plan does not attempt to detail all of the pest management needs. Important areas such as livestock, vegetable and urban pest management are not discussed. Members of the Texas Agricultural Extension Service, Texas Agricultural Experiment Station, Texas Department of Agriculture and United States Department of Agriculture — Federal Research served on committees representing nine geographical areas: High Plains and adjacent Rolling Plains; Rolling Plains; Trans-Pecos; Central Texas Blacklands, West Cross Timbers and Hill Country; Central Texas River Bottoms; Upper Gulf Coast; Lower Gulf Coast and Winter Garden; East Texas and the Lower Rio Grande Valley. In addition, the plan includes a revised review of "TAMU-BUGNET" with innovations and plans for the future regarding computerized information and crop and insect forecasting systems. Each subcommittee submitted individual area plans. The following general format was followed in each of the subplans:

I. Introduction

The introduction discusses the status of major crops, including production practices, pest status and potential losses from key pests. Included is a review of existing pest management programs, estimates of the area-wide impact of the pest management program and expected future economic, environmental and social changes. The plan is designed to extend over 5 years and to meet program needs within that time frame.

II. Proposed Program Strategy

This section reviews the regional strategy of the IPM program, including interactions between crop ecosystems that stress cultural, biological and chemical control of noxious pests. Most subsections deal with early, mid, late season and fall pest management problems. Area-wide pest management implications are given.

III. Program Organization and Extension Needs

The organizational structure of the Texas Agricultural Extension Service is reviewed, as well as relationships between county, district and headquarters Extension staffs and the role of the Texas Agricultural Experiment Station. This section also discusses the possible need to form pest management districts for area-wide coordination of pest management activities. Recommendations for new pest management programs in the next 5 years, to complement ongoing programs, are presented.

IV. Research Needs

The plan discusses research needs for the next 5 years. These needs are coordinated with the 5-year research plan developed by the Texas Agricultural Experiment Station. Research currently in the field validation stage is studied relative to area-wide implementation possibilities.

V. Program Evaluation

Increasing net profit for the farmers of Texas is a primary IPM goal. Economic evaluations presented here demonstrate IPM profitability.

VI. Regulatory Needs

The value and use of certain regulatory processes that support integrated pest management, such as cultural control (planting and crop termination dates), minimization of pest migration and formation of pest control districts, are discussed.

Statewide Organization

The organization of statewide pest management programs requires the involvement of several agencies and producer organizations.

INTEGRATED PEST MANAGEMENT COORDINATOR

The Integrated Pest Management (IPM) Coordinator has sole responsibility for stimulating and coordinating interdisciplinary IPM research, Extension and teaching activities between academic departments within the university. The IPM Coordinator is responsible to the Directors of the Texas Agricultural Extension Service and the Texas Agricultural Experiment Station, and the Dean of the College of Agriculture. The IPM Coordinator works closely with and develops liaison between department heads and project leaders to stimulate the development of multidisciplinary research, Extension and teaching programs, and encourage participation by research and Extension professionals on multidisciplinary IPM teams. The coordinator also encourages the submission of research, Extension and teaching grant proposals to granting agencies in support of multidisciplinary IPM programs; seeks funding opportunities for program support; develops an interdepartmental workshop series for interchange of information; works closely with the Directors' and Dean's staffs to communicate with Texas commodity associations and other organizations which support IPM programs; represents or arranges for representation of The Texas A&M University System at major state, national and international IPM conferences; initiates and coordinates the activities of appropriate individuals in emergency situations such as major pest outbreaks; maintains and expands relationships with other research, Extension, regulatory and teaching agencies to gain information for use in the Texas A&M University IPM programs.

TEXAS AGRICULTURAL EXTENSION SERVICE

The goal of developing a special pest management unit within the Texas Agricultural Extension Service has been achieved. This unit has headquarters, area and county staff members who work with all levels of the Texas Agricultural Extension Service, Texas Agricultural Experiment Station and related agencies.

Extension specialists in horticulture and plant pathology help lead the peanut, pecan, citrus, rice and

soybean programs. An area Extension weed specialist works with pest management programs in the Gulf Coast and Lower Rio Grande Valley.

The Texas Agricultural Extension Service provides professionals to establish and conduct pest management programs at the county level. These county programs are coordinated by the Extension Pest Management Program Leader, whose responsibilities include: coordination of multidisciplinary program objectives; long-range planning; program evaluation; and budget analysis and development. The Extension Pest Management Program Leader also serves as a liaison between agriculture commodity associations, Extension administration and the statewide IPM program. The program leader interprets the statewide program to USDA/Extension staff, is active in IPM program functions at state, regional and national levels, recruits Extension Agents-Pest Management, and shares personnel evaluation responsibilities with Extension administrators at the district and state levels.

The Texas Agricultural Extension Service supports the Texas Pest Management Association (TPMA) and the private consultant industry by providing them with trained scouts and scout supervisors.

TEXAS AGRICULTURAL EXPERIMENT STATION

The Texas Agricultural Experiment Station provides research support in all phases of integrated pest management. Team research will be expanded into several other disciplines in support of citrus, cotton, sorghum, small grains, peanuts, pecans and other crops, to accommodate integrated pest management in an overall production system. Factors involving intercrop relationships will be carefully studied. Production practices such as soil fertility rates, irrigation schedules, row spacing, etc. will be stressed. Developing insect and disease resistant varieties is a major research objective in cotton and sorghum. Also, the most common and troublesome weeds will be identified, and various control strategies will be explored.

TEXAS DEPARTMENT OF AGRICULTURE AND USDA-APHIS

The Texas Department of Agriculture and USDA-APHIS provide leadership in the area of regulatory suppression of noxious pests, including the arranging and organizing of fall boll weevil control programs. The Texas Agricultural Extension Service and Texas Agricultural Experiment Station provide technical support to these agencies.

PRODUCERS AND PRODUCER ORGANIZATIONS

The input of producers in planning, organizing and implementing IPM programs is vital. Producers serve

on local, regional and state steering committees which play an integral part in all programs.

As indicated earlier, producer and commodity organizations have been important to the success of the Texas Pest Management Program (TPMA). In fact, TPMA, chartered in 1977, grew out of the Texas Association of Cotton Producer Organizations (TACPO). TPMA is a statewide, producer-run, non-profit association directing itself toward the advancement of IPM in Texas. TPMA is operated by a board of directors comprised of members participating in the IPM program and commodity organizations supporting IPM programs.

The leadership of TACPO, working closely with scientists and administrators of The Texas A&M University System, realized that the Texas Pest Management Program would soon reach an impasse, because the number of acres and farmers that could be included in the field scouting phase of the program was limited. It was recognized that Extension agents-entomology (PM) could provide effective technical guidance to only about 10,000 crop acres. Texas annually produces cultivated crops on approximately 35.6 million acres of land. The economic impact of cotton, sorghum, corn, rice, soybeans, peanuts, pecans and citrus on the state's economy totaled \$10.91 million in 1979. These crops represent 31 percent of Texas' total agricultural economic impact and 73 percent of the economic impact generated from crop production. *The problem is clear:* How can pest management systems, particularly field scouting, be provided to the majority of the farmers in Texas? How can the pilot pest management program expand to provide IPM to vast acreages? This is the problem addressed by TPMA, i.e., the growers themselves, working with The Texas A&M University System.

A scout supervisor system was devised which would allow moderate expansion of scouting activities. Supervisors would work closely with scouts under the guidance of county Extension entomologists. Extension agents-entomology (PM) would provide technical training and key information to the scout supervisors and producers. In addition, area-wide educational programs would be continued to enhance the flow of technical information developed by research. It is anticipated that by 1983 the transition to the new scout supervisor system will be complete.

PRIVATE CONSULTANTS

The number and quality of private consultants is increasing in Texas. This profession is vital in the expansion of integrated pest management programs. The expanded use of qualified pest management consultants will be continually encouraged, and technical support will be provided to consultants by The Texas A&M University System.

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HIGH PLAINS AND ADJACENT ROLLING PLAINS PEST MANAGEMENT PLAN

The Texas High Plains is an intensely cultivated region containing the greatest acreage of cotton in the state. Grain sorghum has decreased significantly during recent years, with corn replacing sorghum in many instances. The acreages of grain sorghum, corn, wheat and soybeans are much less than that devoted to cotton, but are important to the economy of the region. For many years the area experienced very few insect problems in the production of major crops. In cotton, infestations of the bollworm, *Heliothis zea* (Boddie), and the cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter), required extensive control measures during some years, but damaging infestations were sporadic. The boll weevil *Anthonomus grandis grandis* Boheman, became a threat to the area in the early 1960's. However, the boll weevil population in the Rolling Plains area adjoining the High Plains has been contained by a fall suppression program conducted annually since 1964.

Prior to outbreaks of the sorghum midge, *Contarinia sorghicola* (Coquillett), in the early 1960's, very few insect problems were encountered in grain sorghum production. During the period 1960 to 1963, extensive insecticide usage was required to control midge infestations in sorghum. Since 1963, producers have generally avoided damaging midge infestations and subsequent heavy insecticide requirements by planting sorghum earlier in the season.

Beginning in 1968, massive quantities of insecticide were applied to grain sorghum to combat infestations of greenbugs, *Schizaphis graminum* (Rodani), and secondary pests such as the Banks grass mite, *Oligonychus pratensis* (Banks). Insecticide use in grain sorghum has decreased during the past few years thanks to greenbug resistant hybrids. Corn, which is increasing in acreage in the area, also has received heavy insecticide treatments. Insecticide use in High Plains cotton is still relatively low compared to other areas, but it is increasing.

The Texas High Plains can no longer lay claim to being a relatively insecticide free area. In 1976, more insecticide was used in the High Plains than in any other area of Texas with the possible exception of the Brazos River bottom area of Central Texas.

The area's agroecosystem is simple in structure, and therefore susceptible to disruption. Major disruptions in the agroecosystem may already be occurring. The greenbug and Banks grass mite have developed resistance to several insecticides, and outbreaks of second-

dary pests in all crops are occurring with greater frequency.

Intensive insecticide use in other crops poses a threat of ecological disruption in cotton. Sorghum serves as a source crop for beneficial arthropods which are active in cotton and corn. Sunflowers may also fill this role.

The destruction of beneficial arthropods in source crops may lead to increased pest problems in cotton. In addition, insecticide drift from other crops to cotton also affects beneficial arthropods. Outbreaks of bollworms and cotton aphids in cotton during the past few seasons may be attributed, at least in part, to the disruptive effects of insecticides applied to other crops.

Cropping patterns also play a major role in the stability of the area's agroecosystem. The great reduction in grain sorghum acreage in cotton producing counties may be a significant disruptive factor. The removal of this important source of beneficial arthropods may be partially responsible for increasing pest problems in cotton. The greatly increased acreage of corn provides an ideal early host plant for bollworms and allows the bollworm population to increase prior to the blooming of cotton.

There is a definite trend toward greater insecticide use in cotton. Although pest problems have increased, other factors also are involved. For example, high cotton prices have inspired some producers to apply insecticides regardless of pest population levels in an attempt to ensure good yields. Increasing pest problems and a tendency toward nonjudicious use of insecticides on the part of producers indicate the need for expanded research and the implementation of pest management systems.

Damaging populations of root knot nematode exist on many cotton farms in the "sandyland" regions of the Southern High Plains. It is generally assumed that the root knot is the only problem nematode on the Plains, and that its activity is confined to sandy soils. However, in certain areas of the High Plains, lesion nematodes have been reported in unusually high numbers in hardland soils.

Weed problems on the Texas High Plains continue to increase, even with herbicidal controls available for all crops. The area's predominant species, pigweed, can be adequately controlled by herbicides; however, species of weeds continue to change in each cropping system. With the use of dinitroaniline herbicides in cotton, perennial weeds such as silverleaf nightshade

and nutsedge have greatly multiplied. Annual weeds resistant to DNA type herbicides are morningglory, lanceleaf sage, Devil's claw, cocklebur, flower of an hour, prairie sunflower and others. Better controls are needed for these species. Grassy weeds are the current problem in corn and sorghum because of better broad-leaf herbicides used in these crops. Shattercane, Johnsongrass, barnyardgrass and crabgrass are a few of the problem weeds.

Because of the semi-arid climate and sandy soils, herbicide soil residues create extreme problems for rotational crops. Specific problems occur with triazine herbicides such as atrazine and propazine, and DNA herbicides such as Treflan and Tolban. A strong effort should be made to correlate soil herbicide residue levels to rotational crop response for various soils of the area.

There are presently five pest management programs on the High Plains and the adjacent Rolling Plains. These programs are in: Hale/Swisher counties; Castro/Lamb counties; Crosby/Floyd counties; Scurry/Mitchell counties; Hall/Motley/Dickens/Kent counties; and the Rolling Plains portions of Briscoe/Floyd/Crosby/Garza counties. The first pest management program was begun in Hale County in 1973, and included only grain sorghum during its first 2 years of operation. In 1975, the program was expanded to include corn and sunflowers. Cotton was added in 1976, and now the program includes all four major commodities produced in the area. Cotton now represents the major crop in this IPM program.

The Castro/Lamb and Crosby/Floyd programs were initiated in 1976. Both programs include cotton, corn, sorghum and sunflowers. In 1978, acreage in Castro/Lamb counties was planted mostly to corn. The Crosby/Floyd counties program consists primarily of cotton with some seed sorghum and sunflowers. The programs in the bordering Rolling Plains include only cotton.

One measure of the impact of pest management programs on the High Plains is reflected in the growing number of private entomological consultants. Records indicate that only six private consultants were working in the entire High Plains in 1972. By 1979, some 35 consulting firms were in operation. Educational activities associated with the pest management programs have been instrumental in demonstrating to area producers the value of adopting integrated pest management techniques and using qualified consultants.

The pest management programs have collectively demonstrated proper pest control techniques and new technology to area producers. These techniques and technology have included: 1) management of greenbugs on resistant and susceptible grain sorghum; 2) cultural practices for control of southwestern corn borer; 3) economic threshold and biological insecticides for bollworms; 4) planting dates and timing of insecticides for control of the sunflower head moth; 5) management techniques for other pests, including mites and armyworms; and 6) the value of scouting in making pest management decisions.

Proposed Program Strategy

An efficient crop production system requires detailed soil samples to determine crop fertilization needs and evaluate nematode population levels. Nematode populations should also be monitored at selected times throughout the year on susceptible crops.

Area-wide planting of greenbug resistant sorghums and adherence to established economic thresholds has reduced the pesticide load on grain sorghum with no increase in yield loss. Reducing the amount of insecticide used on grain sorghum helps preserve beneficial arthropods, and thus lowers pest pressure in cotton. However, the reduction in grain sorghum acreage has offset much of this gain. The potential introduction of midge resistant hybrids within the next decade will greatly change sorghum pest management strategies.

Insufficient research information on the corn pest complex has caused excessive use of insecticides on this crop. We can improve this program only with an active research and education effort. The influence of this crop on cotton pest problems remains controversial.

New research in cotton is needed to develop pest management procedures compatible with the changing cropping patterns of the area. However, planting improved short season cotton varieties would, in many instances, prevent damage from late season bollworms. Scouting programs and educational efforts will help reverse the trend toward automatic insecticide applications during the early season.

The High Plains boll weevil suppression program should be continued to prevent the establishment of weevil populations in cotton producing areas.

Program Organization and Extension Needs

There are presently three area Extension entomologists on the High Plains. One is located in Amarillo, and two are in Lubbock on the South Plains. Three Extension agents-entomology (PM) are located on the South Plains, and two in the adjacent Rolling Plains. These staff members work closely with the Lubbock-based area entomologists, and with technical resource personnel from the Texas Agricultural Experiment Station and the Texas Agricultural Extension Service district and headquarters offices. These resource persons include not only entomologists, but also agronomists, weed scientists, plant pathologists, etc. County entomologists work with their respective county Extension agents, who serve as county agricultural program leaders. The county Extension agent, along with the district Extension agent, provides administrative assistance in program development and implementation.

It would be advantageous if area-wide pest management programs could be established on the High Plains. This would ensure that pest management activities directed against key pests were unified and coordinated. However, such programs could only be

initiated after the pest management concept has been demonstrated and accepted by most producers in the area.

The three existing High Plains pest management programs are successfully demonstrating pest management strategies for all major summer crops grown in the area. These include the use of unbiased field scouting, economic thresholds, insect resistant hybrids, conservation of beneficial insects, cultural practices, and selective insecticides and application rates. Approximately 90 percent of the participating producers followed all pest management recommendations made in 1980 by the county Extension entomologists. This indicates a willingness and desire on the part of area producers to incorporate sound pest control strategies in their farming operations.

The present High Plains programs are located in areas which have annual entomological problems. In the Castro/Lamb program area, for example, greenbugs and mites are resistant to most insecticides and miticides. Increased corn production in the Hale/Castro/Lamb counties area may be contributing to the larger bollworm populations observed in recent years. In the Crosby/Floyd counties program, much of the sorghum is acreage devoted to seed production and may receive several insecticide treatments per season, thus affecting the interaction of beneficial insects in corn and sorghum. The two bordering Rolling Plains programs act as a buffer zone for the High Plains cotton acreage, and reduce the impact of the boll weevil on this area.

It is recommended that three additional programs be added during the next 5 years. Multi-commodity programs are proposed for Gaines County, Bailey/Parmer counties and Deaf Smith County. Briscoe County should be included in the existing Crosby/Floyd counties program. The development of these programs will depend upon interest, commodity organizations' support and available funds.

Extension agents-entomology (PM) will be responsible for technically supporting the county pest management programs. These staff members will become more involved in: 1) conducting result demonstrations to show how pest management techniques can be incorporated into production practices; 2) working with nonparticipating producers; 3) assisting with pesticide applicator training and safety programs; 4) using the mass media during the growing season; 5) providing data inputs for BUGNET; 6) helping private consultants, aerial applicators and agri-businessmen with entomological problems as needed; and 7) technically assisting scout supervisors, TPMA, consultants and others involved in pest management. The latter includes conducting scout training schools and helping establish other scout and scout supervisor programs.

Research Needs

COTTON:

Insects

Because of the limited and sporadic nature of cotton pest attacks in the past, there has been little pressure

for cotton insect research in the High Plains. However, changing cropping patterns and ecological disruptions caused by massive insecticide application to other crops has begun to alter the pest situation in cotton.

During the past few years, area-wide outbreaks of cotton aphids and severe thrips infestations have occurred during the early growing season. Increasing damage from bollworm infestations during the latter part of the growing season also has occurred.

Research is needed to define the relationship between pest outbreaks in cotton and actions taken in other crops. Ecological studies are needed to better understand the life systems of major potential pests such as thrips, fleahoppers and bollworms. Economic damage levels and economic thresholds must be established for these pests in High Plains cotton.

The High Plains area will continue to move toward dryland cotton production as the underground water supply diminishes. High insect control costs will be a major hindrance to profitable cotton production. Since the cost of insect control determines the difference between profit and loss in many cotton production areas. In order to maintain profitable production, insect control costs must be kept low.

At present, insect problems and control costs are rising. Evidence indicates that much of the problem is man-made rather than a natural occurrence. An adequate research program will define the problem and help in establishing an economically beneficial pest management system. Research objectives include:

- 1) To investigate the relationship between cotton and other crops concerning the interchange of pests and beneficial arthropods.
- 2) To investigate the effects on cotton of insecticide treatments in other crops, and the influence of cropping patterns on pest problems in major crops.
- 3) To investigate the environmental factors influencing the development of *Heliothis* spp., cotton fleahopper and thrips populations in cotton.
- 4) To determine economic thresholds for potential major pests such as *Heliothis* spp., cotton fleahopper and thrips.
- 5) To develop control systems based on economic thresholds to provide adequate pest control with minimum insecticide usage.
- 6) To investigate the use of short season and resistant cottons to reduce insecticide usage.

SORGHUM AND CORN:

Insects

Previously, High Plains agriculture was a relatively balanced agroecosystem consisting primarily of sorghum and cotton. Early season pest problems on cotton were sporadic, and when chemical controls were used, sorghum could be depended on to furnish beneficial insects to cotton following the mid-August greenbug crash. Excessive insecticide usage for greenbug control upset this balance, but introduction of greenbug resistant sorghums helped reduce insecticide reliance.

During the late 1970's, economics influenced farmers to drastically reduce sorghum acreage and increase cotton and corn production. This changing

crop system altered previous crop-pest interactions and pest management strategies. The role of corn in this new system is unknown, and raises several questions that must be answered for an effective pest management program to continue. Do substantial *Heliothis* move from corn into cotton? Does corn provide any beneficials to cotton? Does heavy spraying of corn for southwestern corn borers and mites influence the pest situation on other crops?

The sorghum situation is unsettled, and future decisions involving production of this crop will have a major impact on pest management strategies in the High Plains. Greenbug resistant varieties have greatly reduced dependence on insecticides. During the next decade, sorghum midge resistant varieties will be available and water will be less available, forcing many producers to grow dryland sorghum. These two events will change agronomic practices, and midge resistance will reintroduce the flexibility of a longer planting period.

Research has a major role in providing answers to these questions. The role of biological control must be emphasized, and new strategies built around changing agronomic practices must be developed. We must reduce insecticide applications to corn. Most of the initial applications are for corn borers and may aggravate mite problems. Cultural control techniques can substantially reduce survival of overwintering larvae, but they are not used by enough farmers. Better education programs should encourage cultural control procedures. Mite resistance to registered insecticides is nearly total, and innovative new management strategies must be developed for controlling this pest. Specific research objectives to answer these questions include:

- 1) To improve sampling techniques and economic threshold information for major pests of sorghum and corn.
- 2) To study movement of pests and beneficials from corn and sorghum to cotton under changing agronomic practices.
- 3) To determine the impact of mites on pest management decisions, and the potential contribution of natural enemies to mites under different cropping systems.
- 4) To develop mite resistance in sorghum and corn.
- 5) To supplement sorghum greenbug resistance with exotic natural enemies.
- 6) To determine changes in agronomic practices and pest management strategies which will occur after introduction of midge resistant sorghum.

- 7) To develop new techniques for managing the southwestern corn borer to minimize dependence on insecticides.

Nematodes

Research is needed to identify the economic status, population dynamics and methods of sampling and control of key nematode species on crops in the High Plains.

Weeds

Several areas of weed science research have been identified for the High Plains. Most of them also could be suggested as priority areas in the Rolling Plains and the Trans Pecos regions. These needs include: (1) studying the biology of major weed species; (2) investigating the potential use of economic thresholds in controlling major weed species; (3) developing technology for sampling weed and weed seed populations in order to determine appropriate herbicides; (4) studying the population dynamics, movement and distributional pattern of weed populations; (5) studying the movement, persistence and adsorption of herbicides in semi-arid soils; (6) determining the behavior of herbicides on specific perennials (penetration and translocation studies); and (7) studying herbicide residues in arid soils on various rotational crops.

Program Evaluation

The economic values of IPM systems and conventional systems will be compared through budget analysis. Aggregate analysis will determine the potential of IPM for large areas.

Regulatory Needs

At present, the use of legislative control as part of a pest management program is not recommended. Management practices best suited for legislative control include plow-up dates for corn stubble and the regulation of cotton planting dates in the boll weevil control zone. However, it is recommended that these practices remain on a voluntary basis. Extension demonstrations and educational programs should continue to be the major means through which these practices are encouraged and adopted.

ROLLING PLAINS PEST MANAGEMENT PLAN

Cotton and cottonseed, the major income crop in the Rolling Plains, accounts for about 38 percent of the total agricultural income. The region plants about 20 percent of the cotton in Texas and harvests 16 percent of the yield. The average yield in the Rolling Plains is about 300 pounds of lint per acre.

Three major factors limiting cotton production in the region are the amount and distribution of rainfall, insects and diseases.

Insects of primary concern are the boll weevil, bollworm, budworm and cotton fleahopper. Most of the insecticide used on cotton fields in this region is for control of one of these pests.

Several cotton pests are of minor importance, including thrips, grasshoppers, beet armyworms and the cotton aphid. Pink bollworms, tarnished plant bugs, yellow striped armyworms, cabbage loopers, cotton leafperforators, cotton square borers, cotton leafworms, stink bugs and spider mites are a potential threat to cotton production.

For the period 1970 to 1973, the combined yield loss from all cotton insect pests in Extension District 3 was 16 percent, with the boll weevil responsible for about 42 percent of this amount. About 46 percent of the cotton acreage was treated with insecticides, with 38 percent of this amount applied specifically for boll weevil control. During this period, the average yield was 169 pounds of lint per acre, and insect control cost an estimated \$2.75/acre.

Based on these figures, total insect and insect control losses averaged \$3.5 million for the years 1970 to 1973. Of this amount, 43 percent, or \$1.5 million, was directly attributable to the boll weevil. Thus, from an economic standpoint, the boll weevil is also the key pest. Insecticides applied indiscriminately during mid-season for boll weevil control can release the bollworm/budworm complex from effective biological control.

For a time, cotton acreage decreased with the advance and establishment of the boll weevil in the Rolling Plains. But beginning in 1978 the trend has reversed. An estimated 110,000 acres, in areas heavily infested with boll weevils, have been brought back into cotton production. Weather factors and uniform planting of cotton have allowed production in these areas with relatively little boll weevil damage.

Localized bollworm/budworm outbreaks occur yearly. Some of these may be the result of insecticides used for boll weevil and fleahopper control. Many growers, in fact, are very reluctant to apply insecticides

at any time for fear of causing a bollworm/budworm outbreak. This problem is most consistent in the irrigated regions of the Rolling Plains. Like the boll weevil, bollworms and budworms are mid to late season pests.

The cotton fleahopper is an early season pest that causes damage in some years. To be economical, fleahopper control must be carried out early in the cotton fruiting period. Insecticides applied for fleahopper control during the third week of squaring or later also destroy beneficials and often result in excessive bollworm damage, thus eliminating any advantage gained by control of the fleahopper population.

Most grain sorghum in the Rolling Plains is grown on dryland because suitable water resources are lacking. About 8 percent of the sorghum was irrigated in 1977. Variable rainfall and soil conditions restrict yields. About 87 percent of the sorghum acreage is in 13 of the 38 counties in Extension Districts 3 and 7. From 1977 to 1979, the number of acres of sorghum harvested ranged from 292,900 to 337,200, and the yield ranged from 24.9 to 35.2 bushels per acre.

The greenbug is the primary pest of sorghum, and has been since the first heavy infestations were observed in 1968. Greenbug populations vary greatly from year to year, with heaviest populations occurring in irrigated fields.

During the past few years, spider mite infestations have been observed in the area. Heavy infestations occur in irrigated fields during some years.

Sorghum midge infestations usually do not occur until late in the growing season. However, infestations have caused extremely heavy damage when sorghum is planted late and over a period of 3 or 4 weeks.

Yellow sugarcane aphid infestations may be increasing; however, economic damage by this pest has not been documented. The yellow sugarcane aphid has a toxic effect on sorghum greater than that of the greenbug, and must be considered a potential threat.

False chinch bugs and conchuela stink bugs feed on the head of sorghum, and occasionally cause economic damage when heavy populations develop. Heavy populations of conchuela stink bugs have developed in Tom Green, Runnels and Knox counties in some years.

Cotton bollworm moths migrate from sorghum to cotton fields as the sorghum begins to mature. This can cause extremely heavy bollworm pressure in cotton fields near sorghum. Irrigated cotton is more heavily infested than dryland cotton, but when enough

moisture is present, dryland cotton can attract heavy bollworm populations.

Producers in Schleicher County have expressed some interest in a pest management program. However, it must be determined whether there are enough acres of cotton harvested in this county each year to justify the program.

Producers in Nolan County have stated that a pest management program may be needed some time in the future; but, to date, their interest has not been well defined.

Pest management programs stressing cultural control and early season control of the boll weevil have been operating in Jones and Fisher counties in District 3, and Tom Green and Runnels counties in District 7, since the spring of 1975. A program was established in Motley, Dickens, Kent, Hall, Briscoe, Floyd, Crosby and Garza counties in 1978. This program has now been split into two programs.

Proposed Program Strategy

COTTON:

Cultural Practices

Uniform planting is a very important part of the pest management program in areas where overwintered weevil infestations are found. The uniform planting date should be based on the optimum planting date. The objective is to prevent some early planted fields from producing large numbers of weevils early in the growing season.

The use of short season or early maturing cotton varieties has shown considerable promise as a pest management strategy. The accelerated fruiting habits of more determinant, early maturing varieties reduce the time of exposure to insects and permit earlier defoliation and harvest.

When compatible with wind and water erosion control, cotton stalks, boll residues and volunteer cotton should be shredded and plowed under to a minimum depth of 6 inches. This practice hastens decomposition of residue and reduces winter carry-over of pink bollworms and boll weevils.

Early Season Pest Management

Chemical control of thrips, fleahoppers and overwintered boll weevils should be used only when necessary as determined by frequent field inspection.

Mid-Season Pest Management

Without an early season or diapause control program, boll weevil infestations may require control measures by the end of July. Insecticides used for boll weevil control at this time often cause outbreaks of bollworms/budworms, and eight to ten applications of insecticide may be required to control these pests. The cost of such a program is unbearable, even for irrigated producers. This situation can be avoided through good management.

The need for bollworm/budworm control should be based on field inspection every 3 or 4 days when populations are increasing. The number of applications that might be needed, the cost of the control program and the expected return should be evaluated carefully before an insecticide is applied. Cotton should not be treated for bollworm/budworm infestations until after blooming. Control measures have not been effective when the tobacco budworm makes up a major part of the bollworm/budworm population.

Late Season Pest Management

The need for boll weevil and bollworm/budworm control after mid-August should be determined by the level of boll damage these pests are causing, the age of the bolls and the probability of maturing the bolls before cool weather greatly slows development. Since boll weevils migrate between fields during this time of year, three or four applications may be needed to allow young bolls to mature sufficiently and escape weevil damage. As many as four or five applications may be required for bollworm control starting in mid-August. Producers must weigh the costs of these late season programs and the expected returns very carefully.

Fall Pest Management Program

In areas where the boll weevil is the primary pest and participation by 100 percent of the cotton producers can be obtained, a diapause boll weevil program should be carried out. As many as five applications of an insecticide may be needed at 10- to 14-day intervals. The diapause control program should be tailored to fit conditions in the area.

SORGHUM:

Crop Rotation

Crop rotation, using various crop or fallow systems, usually results in more stable crop production and more effective disease, insect and weed control. For example, controlling Johnsongrass through crop rotation and cultivation eliminates a competitive weed as well as a possible host plant important to an insect's life cycle. Increased water storage and improved fertility balance are other benefits of rotation as compared to continuous cropping.

Planting Date

To avoid midge damage, area-wide uniform planting dates are recommended. Plantings made after June 15 may have lower yields because of midge damage and inadequate soil moisture or other climatic effects. Optimum planting dates begin around April 15. For highest yields, sorghum should be planted as soon as soil temperatures reach a minimum of 60 degrees F. at seed depth.

Planting Rate

Excessive planting rates on both dryland and irrigated grain sorghum should be avoided. Crowding of plants extends the blooming period, making the crop more susceptible to the sorghum midge. Dryland

planting rates should not exceed 3 pounds per acre in 40-inch rows. For dryland, skip-row planting patterns, about the same number of seed per foot should be used. The ideal stand is two to three plants per foot, five to six plants per foot and eight plants per foot for dryland, limited irrigation and adequate irrigation, respectively. When narrow rows or two rows on a bed are used under adequate irrigation, the planting rate per acre usually remains the same and the number of seed per foot of row should be adjusted accordingly. If seeding rates are increased, they should not be more than 25 percent higher than the rate used in 40-inch rows.

Hybrid Selection

Hybrids should be selected for proven performance in the area. Factors such as yield, standability, maturity requirement, tolerance to important area diseases and resistance to insects are important. Because of high summer temperatures, medium to medium-late hybrids generally produce the highest yields.

Fertilization

Soil fertility and moisture should be considered before fertilization, since moisture reserves under dryland conditions influence the nutrient amounts required for an economical response. Balanced fertility increases a hybrid's yielding capacity, improves water use efficiency and helps the crop mature before insects, heat and drought become a problem. Plants under moisture and/or nutritional stress are more severely affected by insects than are healthy, vigorous plants.

Early Season Pest Management

While sorghum is emerging, and until it is about 6 inches tall, it is susceptible to greenbugs, chinch bugs, flea beetles and lesser cornstalk borers. When these pests are causing damage that will result in significant stand reduction, chemical controls should be used. The greenbug is the most common of the early season pests. With the acceptance of earlier planting dates, movement of greenbugs from small grains to sorghums must be closely monitored to prevent excess early greenbug damage.

Mid-Season Pest Management

The greenbug is the primary pest of sorghum from the time plants are 6 inches tall until they reach the pre-boot stage. Other pests during this time include the corn earworm, fall armyworm, spider mites and the potentially damaging yellow sugarcane aphid. Sorghum should be protected from excess foliage damage caused by greenbugs. Corn earworms and fall armyworms generally do not cause sufficient damage to require chemical control measures. Control of these larvae in the plant whorl usually is not effective, and even when a high level of control is achieved, yields are not significantly increased.

Late Season Pest Management

Late season sorghum pests (from the boot to the hard dough stage) are the same as mid-season pests,

with the addition of the sorghum midge, conchuela stink bug and false chinch bug. Greenbug and spider mite populations can reduce yields greatly during this period. Heavy infestations of stink bugs or false chinch bugs feeding on the developing grain in the head can reduce yields, but as sorghum reaches the hard dough stage, control measures for these pests are no longer needed. The corn earworm can cause significant damage to the developing seeds when the population averages two or more larvae per head.

Sorghum midge damages late blooming sorghum. Eggs are deposited at blooming in the developing florets, and the larvae can prevent almost all seed development causing "blasted" heads. Control measures, to be most effective, must be applied when 25 to 30 percent of the heads have just begun to bloom and there is an average of one midge per head. Two or three applications at 3- to 5-day intervals may be required to control the sorghum midge.

Program Organization and Extension Needs

The Extension agent-entomology (PM) in each county works directly with the county Extension agent in carrying out the Pest Management Program as directed by the county or multi-county steering committee. The area entomologist and other area specialists support the Pest Management Program, working through the county entomologist and the county Extension agent. State entomology specialists give direction to the county program through the district Extension director and area entomologist.

The Extension agent-entomology (PM) calls upon TAES personnel to aid in answering questions on which research is needed.

The objective of the Pest Management Program is to increase income from and efficiency of cotton and sorghum production by applying pest management principles. The Extension agent-entomology (PM) also works with producers on established programs and develops programs as needed to meet the entomological and ecological situations in the county(ies) where he is stationed.

Through pest management programs, new research findings can be implemented and new approaches such as BUGNET (the use of computers in predicting when peaks in bollworm/budworm populations can be expected) can be tried.

The Extension agent-entomology (PM), in cooperation with the county Extension agent and/or appropriate program area committee, conducts demonstrations on research findings and management principles. Data collection for BUGNET comes from the scouting program.

Scouts are hired on the basis of the acreage to be surveyed. If possible, scouts inspect fields in two-man teams. A scout supervisor is employed if indicated by program demands, and if a qualified individual is available. Scouting costs are borne by the cotton and sorghum producers whose land is being inspected.

Scouts are trained by the Extension agent-entomology (PM), with support of the area and state entomologists. The scouting program begins the second week in June and continues until late August.

Research Needs

A research objective is to select, develop and evaluate new short season cottons for use in cotton pest management systems.

Another goal is to evaluate cultural and chemical management practices for current and new short season cotton genotypes. Planting date and early season control tests will be jointly evaluated by entomologists, agronomists and soil science personnel. The objectives are to produce and set a crop before damaging levels of late season boll weevils occur, and to maintain or exceed current yield levels.

One research goal is to investigate the potential of overwintering habitat management. Cooperative efforts have been established between entomologists, range scientists and forest service personnel to investigate shelterbelt and shinnery oak management to reduce the overwintering habitat of the weevil and to improve the shelterbelts and range forage conditions.

Another research goal is to evaluate the effectiveness of boll weevil parasites. The mechanisms that enable *Bracon mellitor* to survive from the time of spring emergence until boll weevil egg-punctured squares are available need to be determined. Additional information is needed on biological control agents that may reduce boll weevil populations in their overwinter habitat.

Other objectives are to study the boll weevil in terms of dispersal and migration, overwintering survival, longevity after emergence in the spring, response to pheromone and colonization pattern in cotton. Ecological studies also will be used to develop selective boll weevil control methods based on cultural techniques and restricted insecticide usage.

Narrow row cotton acreage is increasing in the Rolling Plains. The effect of this planting pattern on boll weevil populations, especially the effect on larval mortality in fallen squares, should be studied.

The bollworm/budworm complex is a problem primarily in irrigated regions of the Rolling Plains,

although outbreaks can occur in any field. Many growers hesitate to apply boll weevil control measures for fear of causing a bollworm/budworm outbreak via destruction of their natural arthropod enemies. Research on the bollworm/budworm problem is aimed at gaining a better understanding of seasonal ecology. The ecology of key *Heliothis* spp. parasites is under investigation, and a large area pheromone trapping program is being initiated. Because *Heliothis* spp. have developed resistance, chemical controls should be evaluated.

Cotton fleahoppers are early season pests. Fleahopper damage thresholds will be determined for short season and insect resistant varieties, such as frego-bract cotton. The goal of cotton fleahopper research is to hasten crop maturity by reducing early season losses.

Program Evaluation

All programs will be evaluated using budgeted or partial budget analysis by comparing program participants with nonparticipants. Area-wide implications will be evaluated.

Regulatory Needs

The need for a uniform planting date in areas where boll weevils are a problem during most years is evident. Where an organized effort has been made, uniform planting dates have worked well. It must be remembered that producers in this area farm primarily dryland cotton, and the spring moisture situation dictates when they will plant. Those producers who farm in weevil infested areas should be prevented from planting in March or April. Cotton planted at this time produces an early first generation of weevils. The cotton producers, through their organizations, have suggested planting dates for their areas. Until they ask for regulations on planting dates, this is the best method for handling the problem.

No other regulatory needs are proposed for the Rolling Plains area.

TRANS-PECOS PEST MANAGEMENT PLAN

The Trans-Pecos area of Texas has three major agronomic crop production regions: El Paso and Hudspeth counties (Region I); Pecos and Reeves counties (Region II); and Martin, Howard, Glasscock, Reagan, Upton and Midland counties (Region III). All the counties except Midland County have insect pest management programs. Principal crops produced in the three regions are cotton, grain sorghum, alfalfa and small grains (wheat and barley). Planted acreage and yield production are shown in Table 1. Crops in Regions I and II are produced under irrigation, while most crops in Region III are produced under dryland conditions.

Production costs vary for each crop and each production region. Production costs and breakeven prices for each crop, under typical crop management, are shown in Tables 2 through 7.

Major cotton insect pests of the Trans-Pecos area are: Region I—*Lygus* spp., stink bugs, cotton bollworm, tobacco budworm and pink bollworm; Region II—cotton bollworm, tobacco budworm and pink bollworm; and Region III—cotton fleahopper, cotton boll weevil, cotton bollworm and tobacco budworm. The incidence of these insects in each production region is influenced by: 1) climate and weather conditions; 2) crop production practices; 3) agricultural cropping systems and crop diversity; 4) cultural control measures; 5) naturally occurring biotic factors; and 6) chemical control.

Cotton yield losses from insect pests vary from one region to another and from one location to another within a region. Estimated annual crop losses from principal insect pests in the three production regions are: 4 to 6 percent in Region I; 10 to 12 percent in Region II; and 3 to 5 percent in Region III.

During the past 5 years, about 40 percent of the cotton acreage in Region I, 70 to 80 percent of the acreage in Region II and 10 to 15 percent of the acreage in Region III has been treated with insecticides each year. In Region III most of the insecticide used was for boll weevil control. During the past 5 years, the average cost of insecticidal controls per acre of cotton has ranged from \$4 to \$20 in Region I, \$10 to \$80 in Region II and \$2 to \$8 in Region III.

The principal insect pests of grain sorghum in Regions I and II are Banks grass mites, greenbugs, cotton bollworms, fall armyworms and the stink bug complex. In Region III the principal insect pests are greenbugs, stink bug complex, armyworms, sorghum midge and the cotton bollworm. Crop yield losses

from these insects vary from year to year. Estimated annual yield losses range from 1 to 10 percent. From 20 to 50 percent of the crop acreage in each production region may receive insecticidal treatments.

Major insect pests of small grain crops are greenbug and other aphids, armyworms and the soil insect complex. In most years, small grain crops escape damaging infestations of these pests. Small grains are important in rotation systems for cultural control of insect pests and as a reservoir of beneficial insect populations. Large numbers of thrips may build up on small grains, and when they migrate at crop maturity, adjacent cotton fields may be threatened.

Cotton pests also include diseases and weeds in addition to insects. These, too, should be considered in an overall integrated pest management program.

The most common cotton diseases are cotton root rot, verticillium wilt, seedling diseases, bacterial blight, fusarium-root knot nematode complex and southwest cotton rust. Any one of these disease situations can limit cotton production. The overall loss to disease in the Trans-Pecos area is estimated at between 10 and 15 percent annually.

Cotton disease control depends heavily on proper cultural practices and variety selection. Certain cultural practices reduce both insect numbers and disease incidence. This has been noticed particularly in Reeves and Pecos counties where cotton diseases have been closely related to agronomic practices. While major disease losses are not as common here as in previous years, a small part of the crop is lost annually to a variety of diseases. Factors associated with disease losses are over-watering, over-fertilization and lack of crop rotations.

In the early 1960's, verticillium wilt caused heavy losses in many cotton fields. The principal variety was Acala 1517, which has an indeterminate growth pattern that encouraged producers to irrigate late in hopes of making additional top crop. The common practice of applying anhydrous ammonia in each irrigation, by releasing it into the head ditch, further compounded the problem. When plants were defoliated early by diseases such as wilt and bacterial blight (Leaf Spot), weed problems often occurred which interfered with harvest operations. The reduced cotton acreage in the late 1960's, and the use of determinate varieties, allowed more time to prepare land for alternate crops which improved soil conditions and reduced the weed problem in cotton. New varieties with varying levels of disease resistance have further reduced losses.

In the past, heavy preplant irrigation along with early planting dates combined to cause early seedling problems. The cold soil slowed growth and predisposed the seedlings to attack by numerous organisms in the seedling disease complex. When seedling roots were damaged, the plants responded slowly to additional water and nutrients. Weeds were able to gain a foothold and thin stands resulted. The heavy growth of foliage toward the end of the season encouraged insects, especially bollworm moths, to deposit eggs. Increased insecticide costs were thus coupled with late and poor crops, adding to the producer's losses.

With the change to more determinate varieties, producers could plant later under more favorable soil conditions and eliminate late season growth and pesticide spraying. This reduced major disease losses. In such a system, less water and fertilizer are needed, and can be saved for soil-improving crops. These cultural practices fit in well with narrow row spacings and aid in reducing weed competition, verticillium wilt and insecticide costs. Planting high quality cottonseed under more favorable soil conditions largely prevents seedling disease losses. Disease loss estimates have been reduced in the Trans-Pecos area from 15 percent in the early 1960's to 10 percent in recent years. This change was the result of smaller planted acreage and more diversified cropping systems.

Weed management is an integral part of pest management. Reliance on dinitroaniline type preplant herbicides has increased the incidence of certain resistant weeds such as nightshade and rough blackfoot. Cultural and chemical programs should be designed to control designated target weeds, and discourage the use of general herbicides.

Proposed Program Strategy

Program Components

The Pest Management Program for the Trans-Pecos area is designed to achieve pest control based on sound economic principles which integrate cultural, biological and chemical methods into a practical program. It is a year-round program, and the producer has a key role in its success.

Agronomic and cultural practices are important to successful pest management in the Trans-Pecos area. Correct land preparation ensures a good seedbed for planting and aids in destruction of crop residue, insects harboring in soil or plant debris in fields, plant disease organisms and weeds. Use of proper planting dates aids in seed germination and plant development, and helps seedling plants escape injury from insects and plant diseases. Good quality planting seed ensures better seed germination and enhances plant vigor. Producers should select varieties adapted to the production area that can be managed for early crop maturity. If diseases are prevalent, resistant varieties are important.

Irrigation, fertilization and cultivation also are important in a pest management program. These practices should be manipulated to attain early crop

maturity and optimum yields with minimum cost. Production practices should be carefully monitored in order to avoid field and plant conditions favorable for insect pests, plant disease organisms and weeds.

Weed control ensures better crop performance and suppresses insect pest populations. Crop rotation systems usually improve the soil, allow greater water conservation and reduce insects and diseases. Crop rotation also may increase crop yields. Harvesting efficiency helps suppress certain insect pests and may increase crop profits.

Proper use of biological and natural controls is essential to the success of a pest management program. Crop diversity in rotation systems helps conserve insect predators and parasites in a production area. Field insect scouting is vital in assessing the performance of insect predators and parasites in suppressing insect pests.

Chemical controls are important, but should be used intelligently and judiciously in order to avoid complete disruption of the natural control complex. In insect pest management, scouting is the most important tool in determining the need for a chemical or biological agent.

This proposed pest management program will not rely simply on cultural controls or the use of any single control or suppression technique. Rather, it is an integrated approach to pest control that uses various control methods and considers the role of all types of pests in the environment, interrelationships among insects, interrelationships of agronomic production practices and pests, the effect of crop diversity on pest populations and other factors.

A PROPOSED FIVE-YEAR INSECT PEST MANAGEMENT PROGRAM PLAN

The objective of the Trans-Pecos Pest Management Program is to implement programs that are efficient, economical and ecologically sound, and which will help agricultural producers increase net profits.

Educational programs and activities should accomplish specific goals, including:

- 1) Teaching producers to recognize key, secondary and occasional insect pests of crops, and the types of injury each causes.
- 2) Teaching producers to recognize beneficial insects (predators and parasites) associated with crops in the area.
- 3) Helping producers understand the impact that cultural, mechanical, physical, biological, chemical and regulatory control methods have in field manipulation of insects pest populations.
- 4) Establishing field monitoring of crop insect pests, natural enemies, crop development and crop production inputs to determine the need for various control strategies.
- 5) Developing field monitoring training programs for scouts, growers, private and commercial consultants, county Extension agents and others.
- 6) Helping producers recognize the interaction of different crops in a cropping system, and the impact of

that interaction on insect pests and beneficial arthropods.

- 7) Organizing producers in community and area-wide insect management programs, and assisting producers in program coordination and evaluation.
- 8) Using insect surveillance to keep producers aware of present and expected insect activity.

Proposed pest management strategies include:

- 1) Insect scouting and crop monitoring. Crops should be scouted on a weekly basis, except during critical periods of crop development and insect pest activity when crops should be scouted every 2 to 4 days.
- 2) Using cultural, biological, natural, physical and mechanical insect control methods to greatest advantage.
- 3) Selecting and using chemical controls intelligently.
- 4) Planting early maturing cotton varieties to escape late season pest problems and unfavorable weather conditions.
- 5) Planting insect resistant varieties when it is feasible to do so, and the varieties are available for commercial production.

Programs must meet two vital criteria for producer endorsement:

- 1) Producers must recognize suggested pest management practices as acceptable and technologically sound.
- 2) Suggested pest management practices must be economically feasible.

Program Organization and Extension Needs

The Trans-Pecos program should be structured to allow maximum input from all agencies, producer associations, producers, consultants, agribusiness representatives and industries associated with agricultural crop production in the area. It is recommended that Midland County be included in the existing pest management program (Region III), and that this program be divided, which will require an additional Extension agent-entomology (PM).

Grower Steering Committee

There should be a steering committee comprised of key producers within a given pest management area or county, agribusiness representatives, private agricultural consultants, commodity association directors, county Extension agents and Extension agents-entomology (PM). A producer should serve as chairman of the committee.

The Extension agent-entomology (PM) should:

- Help producers plan and coordinate insect pest management programs in an area or a county.
- Form and cultivate a working relationship with agri-industry personnel, private consultants and other agribusiness representatives in the program area.

- Provide technical assistance on field crop demonstration projects that involve insect management techniques.
- Help county Extension agents plan, implement and evaluate educational programs to gain producer endorsement and adoption of insect pest management practices.

The county Extension agent should:

- Assist the Extension agent-entomology (PM) with program planning, implementation and evaluation.

The state Extension and research disciplines should:

- Provide technical assistance on program planning, implementation and evaluation.

The area Extension entomologist should:

- Coordinate insect pest management programs in the area.

The Trans-Pecos Pest Management Advisory Committee

This committee includes area Extension and research disciplines, Extension agents-entomology (PM), county Extension agents-agriculture, the district Extension agent-agriculture and area research center directors. This technical committee should:

- Review the progress of pest management programs in the area.
- Provide technical assistance on pest management projects or programs.
- Identify research and Extension needs for support of pest management programs.

Role of Extension agent-entomology (PM)

The primary role of the Extension agent-entomology (PM) is to educate producers on concepts of integrated insect pest management. Specific responsibilities of the Extension agent-entomology (PM) are:

- 1) Assisting the local pest management steering committee in hiring qualified scout supervisors, and coordinating scouting activities with the TPMA.
- 2) Helping producers locate insect consultants or producer-hired scouts.
- 3) Coordinating annual scout training schools.
- 4) Helping consultants or producer-hired scouts with field report analysis and decision making.
- 5) Helping producers coordinate and evaluate intensive community or county pest management educational programs.
- 6) Assisting the county Extension agent with field demonstrations of insect pest management practices.
- 7) Operating insect surveillance traps in the program area to keep producers updated on present and expected insect activity.

- 8) Coordinating field tours so that producers can learn to recognize insect damage and proper scouting techniques.
- 9) Helping the county Extension agent with pesticide applicator training and safety programs.
- 10) Compiling information regarding production practices in the area for evaluation of pest management programs.
- 11) Collecting and analyzing field data on insect population trends.
- 12) Assisting the county Extension agent with general entomological problems in the county.
- 13) Providing information to the program building committees that relates IPM to the total Extension program.

Research Needs

The cropping system in the Trans-Pecos area of Texas includes winter small grains, alfalfa, cotton, grain sorghum, vegetables, sunflowers and forage grasses. Potential also exists for a tortilla corn industry, provided that certain entomological problems are solved. Crops grown in the Trans-Pecos area are often located in close proximity to one another or to the diverse natural flora. Thus, the agroecosystem in this part of Texas is more complex than the simpler cotton-grain sorghum ecosystem existing in much of the state.

The following research objectives are needed for development and support of an integrated pest management program in the Trans-Pecos:

- 1) To establish simplified and reasonably accurate sampling procedures for *Heliothis* spp., *Lygus* spp., pink bollworm and spider mites. This step may be expedited by modification and/or verification of sampling procedures used for the same or related arthropods in other agricultural areas in desert climates (e.g., Arizona, New Mexico and California).
- 2) To determine economic threshold levels for principal arthropod pests of each crop.
- 3) To continue investigations of irrigation efficiencies in crop production, and establish the effects of irrigation on arthropod population levels.
- 4) To continue developing crop varieties which will mature early and resist arthropod damage.
- 5) To study the biology and phenology of arthropods infesting area crops, and establish the relationships between arthropods and their natural and cultivated host plants.
- 6) To investigate the considerable opportunities for biological control in the Trans-Pecos area. Exotic natural enemies are available from biological control projects in other desert agricultural regions of the United States. The insect pests for which natural enemies are currently available are *Heliothis* spp., *Lygus* spp., *Pectinophora gossypiella* and tetranychid mites.

Entomological Research Needs:

- 1) *Lygus* — cotton, alfalfa
 - A. Seasonal population trends.

- B. Economic threshold on cotton.
 - C. Interrelationship of cotton-alfalfa *Lygus* populations.
 - D. Status of natural and cultural controls.
 - E. Insecticide efficacy.
 - F. Assessment of *Lygus* as a secondary pest.
 - G. Methods of field sampling for populations and damage.
- 2) Spider mites — sorghum, corn, cotton (alfalfa and wheat as reservoir)
 - A. Species composition.
 - B. Introduction and evaluation of exotic natural enemies.
 - C. Cultural control techniques.
 - D. Pesticide efficacy.
- 3) *Heliothis* complex — cotton, sorghum, corn, alfalfa
 - A. Assessment of damage (or potential).
 - B. Seasonal phenology.
 - C. Efficacy of natural control mechanisms (endemic parasites, predators and disease pathogens).
 - D. Impact of adjacent crops (cotton-corn, cotton-sorghum, cotton-alfalfa)
 - E. Insecticide efficacy (including microbials).
 - F. Efficacy of released parasites (*Trichogramma* spp.)
 - G. *Heliothis* immigration in the area.
 - H. Crop irrigation timing to avert field infestations.
- 4) Boll Weevil — cotton
 - A. Overwintering habitats in Howard, Glasscock and Reagan counties.
 - B. Overwintering habitat management for boll weevil population suppression.
 - C. Biological control agents.
- 5) Alfalfa Weevil — alfalfa
 - A. Economic threshold.
 - B. Biological control efficacy.

Crop Management Research Needs:

- 1) Irrigation
 - A. Pumping plant efficiencies, particularly in terms of energy efficiency.
 - B. Conveyance system improvements to minimize losses.
 - C. Field distribution systems to ensure adequate wetting of crop root zones without excessive losses from deep percolation, run-off and/or evaporation.
 - D. Economics of water use.
 - E. Salinity control under limited irrigation.
- 2) Soil Fertility
 - A. Level of nutrients required for profitable crop production under various management alternatives.
 - B. Relationship of crop rotations to improvements in soil physical conditions and efficient fertilizer use.
 - C. Development of more efficient distribution methods.
 - D. Economics of fertilizer use.

- 3) Weed Control
 - A. Value and effectiveness of crop rotations in weed control.
 - B. Development of chemical weed control systems to minimize requirements of hand labor.
 - C. Relationship of weed infestations to economic losses.
 - D. Economics of weed control methods.
- 4) Cultivars
 - A. Development of cultivars that respond favorably to limited resource inputs.
 - B. Development and maintenance of insect and disease resistance in suitable cultivars.
- 5) Economics
 - A. Interrelationships among inputs and their economic effects.

Program Evaluation

The economic impact of the pest management program should be evaluated by comparing costs and returns of participating and nonparticipating produc-

ers. Field records on the reduction of insect pest populations and crop damage from pests should be studied. Producers will supply information on program effectiveness and the mechanics of incorporating pest management practices into crop production systems. Also, the impact of the program on the amounts, rates, application methods, etc., of insecticides used in crop production should be evaluated.

Special Extension programs have increased significantly since 1976 in the Trans-Pecos area. Insect pest management programs, under the supervision of Extension agents-entomology (PM), have been established in the three agronomic crop production regions of the area. Expanding educational activities would require demonstration aides to assist the county Extension staffs.

Regulatory Needs

Area regulations on cotton residue destruction for pink bollworm control should be enforced along with present state insect quarantines.

**TABLE 1. Crop Acreage and Average Yield in Three Regions of Trans-Pecos
Insect Pest Management Program Area (5-year average, 1971-1975)**

Region (Counties)	Crop	Planted acreage	Irrigated acres	Average yield	Dryland acres	Average yield
I El Paso Hudspeth	Cotton					
	Upland	20,400	20,400	603 lb. lint	---	---
	Pima	22,589	22,589	374 lb. lint	---	---
	Grain sorghum	3,900	3,900	48.13 bu.	---	---
	Alfalfa	24,280	24,280	6.28 tons	---	---
	Small grains (wheat & barley)	6,880	6,880	66.19 bu. wheat 5.32 bu. barley	---	---
II Reeves Pecos	Cotton					
	Upland	29,730	29,730	673 lb. lint	---	---
	Pima	9,276	9,276	399 lb. lint	---	---
	Grain sorghum	14,600	14,600	55.33 bu.	---	---
	Alfalfa	7,375	7,375	5.4 tons	---	---
	Small grains (wheat & barley)	24,675	24,675	38.73 bu. wheat 40.69 bu. barley	---	---
III Martin Howard Glasscock Reagan Upton Midland	Cotton	229,552	45,014	530 lb. line	184,538	345 lb. lint
	Grain sorghum	51,400	3,800	52.07 bu.	47,550	24.14 bu.
	Alfalfa	---	---	---	---	---
	Small grains (wheat & barley)	8,380	---	---	8,380	13.5 bu. (wheat)

¹Data from Texas Crops and Livestock Reporting Service

TABLE 2. Cost of Producing Upland Cotton in Trans-Pecos

Item	Region I	Region II	Region III Irrigated	Region III Dryland
	-----\$/acre-----			
Variable	210	381	86	38
Fixed ¹	14	61	17	10
Harvest	<u>96</u>	<u>74</u>	<u>58</u>	<u>38</u>
Total	320	516	161	86
	-----lbs/acre-----			
Avg. Yield	603	673	530	345
	-----\$/lb.-----			
Break-even Price ¹	\$.45	\$.69	\$.22	\$.17

¹Does not include land or management charges.

TABLE 3. Cost of Producing Pima Cotton in Trans-Pecos

Item	Region I	Region II
	-----\$/acre-----	
Variable	203	383
Fixed ¹	13	61
Harvest	<u>64</u>	<u>62</u>
Total	280	506
	-----lbs/acre-----	
Avg. Yield	374	399
	-----\$/lb.-----	
Break-even Price	\$.67	\$1.19

¹Does not include land or management charges.

TABLE 4. Cost of Producing Grain Sorghum in Trans-Pecos

Item	Region I	Region II	Region III Irrigated	Region III Dryland
-----\$/acre-----				
Variable	121	152	53	22
Fixed ¹	11	41	17	9
Harvest	<u>22</u>	<u>18</u>	<u>18</u>	<u>14</u>
Total	154	211	88	45
-----cwt/acre-----				
Avg. Yield	27	31	29	14
-----\$/cwt-----				
Break-even Price ¹	\$5.70	\$6.80	\$3.00	\$3.20

¹Does not include land or management charges.

TABLE 5. Cost of Producing Alfalfa in Trans-Pecos

Item	Region I	Region II
-----\$/acre-----		
Variable	87	223
Fixed ¹	86	208
Harvest	<u>135</u>	<u>116</u>
Total	308	547
-----tons/acre-----		
Avg. Yield	6.28	5.40
-----\$/ton-----		
Break-even Price	\$49	\$101

¹Does not include land or management charges.

TABLE 6. Cost of Producing Barley in Trans-Pecos

Item	Region I	Region II
	-----\$/acre-----	
Variable	148	186
Fixed ¹	6	51
Harvest	<u>19</u>	<u>13</u>
Total	173	250
	-----bu/acre-----	
Avg. Yield	55.3	40.7
	-----\$/bu-----	
Break-even Price ¹	\$3.13	\$5.40

¹Does not include land or management charges.

TABLE 7. Cost of Producing Wheat in Trans-Pecos

Item	Region I	Region II	Region III Irrigated	Region III Dryland
	-----\$/acre-----			
Variable	153	143	—	19
Fixed ¹	6	34	—	4
Harvest	<u>21</u>	<u>13</u>	—	<u>16</u>
Total	180	190		39
	-----bu/acre-----			
Avg. Yield	66.19	38.73		13.5
	-----\$/bu-----			
Break-even Price	\$2.72	\$4.91		\$2.89

¹Does not include land or management charges.

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BLACKLANDS, WEST CROSS TIMBERS AND HILL COUNTRY PEST MANAGEMENT PLAN

The Texas Blacklands area runs from the central Texas area north to the Oklahoma border. Diversified agricultural production in this area includes sorghum (1.3 million acres), small grains (1.3 million acres), cotton (0.4 million acres), pecans (0.2 million acres) and peanuts (0.15 million acres), with a large acreage devoted to livestock production. Minimal production inputs make yields very dependent on weather conditions. Depending on the type of season, net returns per acre can be some of the highest in the state.

One of the nation's most successful pilot pest management programs has been implemented in the Blacklands region of Texas. The production characteristics and ecological parameters inherent in this area are ideal for pest management.

The primary accomplishment of pilot programs in the Texas Blacklands is the increased net return to program participants. The Hill/Ellis counties Pest Management Program began in 1972. A project was initiated in 1973 in Comanche County to develop management strategies for more profitable peanut production. As a result of the success of the Hill/Ellis program, additional programs in Williamson/Milam, Bell/Falls, Collin/Hunt, Johnson and Navarro counties were implemented in 1976. Reduced and more precise use of pesticides has resulted in an improved agri-eco environment. Other accomplishments of the pilot programs include: personal producer confidence in county entomology specialists; producer recognition of the benefits of field scouting; changes in basic producer attitudes regarding the philosophy of applying all control measures on an as-needed basis; and producer realization of the importance of cultural and biological control factors, and the use of pest resistant plants.

The success of pilot pest management programs indicates that producers are willing to adopt new farming practices when they are demonstrated and presented in a meaningful, educational program.

Peanut acreage in this geographical area of the state comprises one-half of the Texas allotment. Peanuts are produced in a mono-culture system in the West Cross Timbers area. Present pest management strategies in Comanche County include the following items: understanding economic thresholds of the lesser cornstalk borer and leaf-feeding insects; forecasting procedures for leaf spot control; sampling for and satisfactory control of nematodes; soil inoculation practices for plant nutrition; crop rotation; and herbicide applications for nutsedge control.

The Williamson County Pecan Program was implemented in 1976 in the Georgetown area. The pecan is native to Texas. Native and "improved" trees total about 22.8 million and grow on 8,000 to 10,000 acres. The recommendations developed in this section of the plan apply to pecans in other areas in the state, with the exception of West Texas. Pecans are produced in two very different cultural systems in the Blacklands area. Native pecan timber occupies approximately 0.5 million acres along local streams and rivers. Some native trees are chemically treated for pests if there is a potential for a good crop of nuts. Little management technology is used during the years when nut set is light. Improved varieties of pecans are cultivated on 0.1 million acres in the Blacklands. These trees are extensively managed for control of plant diseases, insects, weeds and soil fertility.

Devastating yield losses can occur annually from two major insect pests. The pecan weevil and pecan nut casebearer can reduce pecan yield by 20 to 80 percent, depending on population pressure. Secondary insect pests which can become major pests at various times include the hickory shuckworm, aphids and several leaf feeding caterpillars. Pecan scab and root knot nematodes are major pathological problems which lower nut quality and yield in the Blacklands.

Pecan result demonstrations in Parker, Cooke, Williamson, Ft. Bend, Anderson, Tom Green, Caldwell and Guadalupe counties have used IPM methods to manage pests in improved and native orchards. Result demonstrations will be expanded in 1981 to include Bowie, Brazos, San Saba and possibly two other counties. Pests have been held below economic levels using fewer pesticides than are used with a conventional calendar date spray method. This is facilitated by weekly foliage pest surveys, monitoring of plant stages and surveys of nut feeders at times when they are expected to occur. A pecan scab advisory for the area surrounding each station is issued according to humidity and temperature measurements recorded at each location. This scab advisory program has resulted in more effective timing of fungicide application, and a reduction of fungicide use in many cases.

Most crop producers in this area follow a cotton, sorghum, small grain rotation. This diversification allows the distribution of equipment and management time over the entire production year. Management decisions relating to grain sorghum production have a direct bearing on insect populations which will subsequently develop in adjacent cotton fields.

Typically, the Blacklands producer uses a limited number of insecticide applications for controlling major insect pests. The dependence on cultural practices coupled with biological control systems is necessary to produce a low-cost cotton crop. The successful cotton producer may apply one or two insecticide applications in early season for thrips control, and one to three applications to control the boll weevil. In most instances, these insecticide applications are sufficient to produce a profitable cotton crop. A single insecticide application may be used to reduce fleahopper numbers if damaging populations develop.

Successful cotton producers who have implemented pest management strategies for the past 2 years are using a short season, quick fruiting, semi-determinate variety. The "earliness factor" has a dramatic effect on cotton production. Earliness is needed to escape damaging mid and late season insects.

Insect damage reduces cotton yield by approximately 40 to 45 pounds of lint per acre. The boll weevil is responsible for a yield loss of 15 to 18 percent in most Blacklands counties. It is estimated producers could increase lint yields by 60 to 90 pounds per acre with an effective pest management system. Insecticide use would not be significantly reduced or increased, but greater efficiency would be achieved. Some poor managers lose up to 80 to 90 percent of the crop from a combination of insect pests. Some of the highest boll weevil losses in Texas occur on individual farms in this production area.

Blacklands sorghum producers annually experience a 10 to 18 percent yield loss from sorghum midge. Midge populations are occurring earlier in the production season, and insecticide treatments have increased dramatically during the past 2 years. The planting date is more critical for sorghum than for cotton. Late planted sorghum develops tremendous insect populations and weather damage also can be a problem.

Phymatotrichum (cotton) root rot is the most serious disease of cotton in the Blacklands of central Texas. The disease has been controlled by soil fungicides and fumigants; however, these approaches have not been economical at present market prices. Fungicide application will be an annual expense, but the cost of soil fumigation can be prorated over a 3- or 4-year period. There are no resistant cotton varieties available at this time.

Before the development and implementation of the Blacklands Cotton Pest Management Program, producers applied insecticides automatically about every 10 days once cotton came up to a stand, and terminated pesticide use on a predetermined calendar date. This strategy quickly led to a breakeven economic situation, and the development of resistance of certain key insect pests. Mid and late season insect programs caused financial ruin for some cotton growers. Because beneficial insect species and natural control agents were destroyed, secondary pests become major pests and so even more insecticides were needed.

The pilot pest management studies conducted in Texas indicate that Blacklands producers can expect a high return for dollars invested in pest management. The input cost of pest management practices is rela-

tively low because of the significant impact of cultural and biological agents present in the environment. Many management procedures do not add additional expense to the farming operations, but are effective because of their timeliness.

The Blacklands region contains five major metropolitan areas. An urban pest management program centering on turf, ornamentals and related areas should be implemented within the next 5 years.

Proposed Program Strategy

COTTON AND SORGHUM:

Major objectives of the Blacklands Pest Management Program are to increase producers' net returns, provide boll weevil management, reduce root rot losses, reduce sorghum midge losses, and reduce plant disease losses in small grains. Tools for achieving these goals include: resistant and improved crop varieties; crop modeling techniques; and new farming practices such as narrow row planting and planting date regulation.

Cultural control activities are the key to successful pest management programs in the Blacklands. Factors such as planting date, harvest date, stalk destruction and plow-up dates, and other farming practices are vital components of the program.

Early harvest in late August and early September, followed by the complete destruction of plants, should be mandatory. Green cotton in the field after September 5 must be plowed down or sprayed with insecticide to prevent an excessive build up of boll weevil populations. If wet weather delays harvest and stalk destruction, a fall diapause control should be used. This cultural tool is also the major means of reducing pink bollworm populations.

The crop rotation system which should be used is a sorghum, cotton, small grain rotation. This system reduces insect pests and plant diseases and helps conserve soil and water.

Strict adherence to spring planting dates for cotton and sorghum is important. Ideally, producers in this area should plant sorghum as soon as the threat of spring frost is over. Cotton is planted in late March or early April. Producers south of Ellis County should have their cotton planted and up to a stand by May 1. All producers north of Ellis county should have their cotton up to a stand by May 15. Sorghum planted after April 15 is more susceptible to insect damage.

The varieties of sorghum and cotton planted are very important to the success of the program. Producers should plant a rapid fruiting, early maturing, semi-determinate type of cotton. This cotton survives better in colder soil after germination, and provides the "earliness factor" which lessens the threat of mid and late season insect damage and drought.

Mechanical and chemical weed control practices also are vital management tools. Most producers use a broad spectrum, preemergence herbicide and follow with mechanical cultivation. Producers are urged not to delay crop development with the excessive use of

MSMA as a postemergence herbicide. Certain cotton varieties (Quapaw, GSA-71, GSA-75) have demonstrated a tolerance to MSMA.

Ecosystem diversity and the abundance of beneficial insect species in this cropping system reduce the need for many insecticide applications. The major cotton insect pests requiring management in the Blacklands area include thrips, boll weevils, fleahoppers, tarnished plant bugs and bollworms.

Producers must rely on beneficial insects for the control of cotton bollworm and tobacco budworm. The expected yield potential of Blacklands cotton does not allow for insecticide programs which satisfactorily control bollworms and budworms. Late season insect control programs are used to protect the developing fruit from damaging infestations of boll weevils.

PEANUTS:

Peanut producers could benefit greatly from a pest management system, because insecticides often are applied needlessly to control thrips and certain foliage feeding insects. A pest management program would help control not only these insects, but also the lesser cornstalk borer and peanut diseases. Producers need a systematic approach to controlling soil-borne diseases, and more information on the role of crop rotation in lessening the severity of certain leaf spot diseases.

Southern blight in peanuts is a perennial problem. A scouting program using climatic measurements, air drainage of fields and hydrothermograph readings in each field would provide data to help producers control southern blight.

The major objectives of a peanut pest management program include:

- 1) Less pesticide use on non-economic thrips infestations.
- 2) Timely applications of fungicides for disease control.
- 3) Weather monitoring programs.
- 4) Correct diagnosis of diseases and the proper selection of fungicides to control them.
- 5) Lesser cornstalk borer detection and management approaches.
- 6) A systematic approach to soil-borne diseases and the development of management programs for their control.
- 7) Investigation of the use of PCNB for disease control in some fields.
- 8) Regular sampling of nematode populations to determine damage potential.
- 9) Systematic sampling, identification and control of key weed species.

PECANS:

Trees in native pecan groves are often too dense to produce consistently high-quality nut crops. Result demonstrations in Williamson County have shown that thinning trees increases production through improved disease prevention. Removing weak trees susceptible to pecan scab improves air circulation, facilitates drying of foliage and results in a lower inci-

dence of pecan scab. Weak, unproductive trees are no longer sprayed unnecessarily. Often, the initial cost of thinning can be offset by selling marketable timber as veneer, sawlogs and fuel wood.

A pecan scab monitoring program which measures the accumulated hours of 90 percent relative humidity in the 70 to 95-degree F range has proved effective in IPM orchards. This monitoring program could be expanded with increased grower participation.

Stem end blight, a serious pecan disease, contributes significantly to the August nut shed. Control measures consist of monitoring the nut development and spraying a fungicide when the water stage is reached. This method of sampling is simple and treatments based on the water stage have proved effective.

Timing of nut casebearer sprays is based on nut inspection for eggs. The economic threshold has been defined as 1 percent egg lay for the first generation and 2 percent for the second generation. Without treatment, these levels have caused significant nut loss. However, it is evident that this threshold needs to be adjusted to varying crop loads. Current TAES research may refine this economic threshold.

Degree days, light traps and tree bonding have all been used to indicate when to start nut inspection for the nut casebearer. Although these techniques require specialized resources, fewer hours of in-the-field inspection for casebearer eggs will be necessary if these methods are developed properly.

Cone emergence traps, tack traps, limb jarring and knockdown sprays have been used to detect the adult pecan weevil. These methods, although not widely used, offer a valuable tool to growers in an IPM pecan weevil management program because they indicate when treatments are needed. Monitoring nut development is also important to growers using IPM methods, as research has shown that weevils cannot reproduce in nuts before the late gel or early dough stage is reached. Once nuts are in the late gel stage, and weevils are found by using one or more of the adult weevil monitoring methods, then insecticides for control are applied.

There is increasing evidence that pecan weevils emerge from the ground at approximately the same time each year, beginning in late August and ending in mid-September. This holds true if adequate soil moisture allows for free movement of adults out of the ground at the predetermined time. A Julian day prediction model is currently under development by TAES to project when pecan weevils will emerge. This prediction model should be delivered to growers in pecan weevil areas as early as 1981.

Program Organization and Extension Needs

Pest management programs will offer educational activities for private consultants, producers and field scouts. Major emphasis will be on developing, supporting and training of personnel to work with TPMA

and the private sector to expand acreages using pest management techniques.

Special training meetings and workshops will be provided for consultants, growers, agri-business personnel, scout supervisors, field scouts, chemical company representatives and pesticide dealers. These persons will be trained in new techniques and principles of pest management.

Area training schools for scouts, consultants, growers, county Extension agents and Extension agents-entomology (PM) will be conducted during early spring before crops are planted. Continuing programs and resource personnel will provide support.

A timetable of program goals is as follows:

Year 1 — 1981

- 1) Evaluate economic thresholds for green bugs and white grubs on wheat.
- 2) Begin field evaluations of midge resistant sorghum lines.
- 3) Collect field data to document the degree-day model for pecan nut casebearer and a predictive model for pecan weevils.
- 4) Evaluate Dimilin and Imidan for boll weevil management.
- 5) Continue the Blacklands Pest Management Scouting School.
- 6) Provide Moth ZV3 predictions for the occurrence of the *Heliothis* complex.
- 7) Predict boll weevil population emergence with pheromone traps and estimate populations by field sampling.
- 8) Demonstrate a farming system which uses minimum inputs to keep farmers competitive in the market place.
- 9) Train county staffs on new chemical products.
- 10) Develop a management system to reduce aflatoxin problems in harvested plants.
- 11) With the assistance of the Extension agent-horticulture (PM), demonstrate methods and benefits of native pecan grove thinning.
- 12) Develop a pecan scab monitoring program using hydrothermographs in strategic pecan producing areas.
- 13) Integrate adult weevil monitoring and nut development surveys into the pecan weevil management program, and establish the program in grower orchards.
- 14) Conduct training meetings on Pecan Integrated Pest Management methods for growers and industry representatives.

Year 2 — 1982

- 1) Implement personnel requirements.
- 2) Evaluate wheats resistant to the greenbug.
- 3) Implement a modeling program for sorghum pests.
- 4) Define the interaction of the cotton-sorghum ecosystem in relation to major pest complexes.
- 5) Make Moth ZV3 predictions.
- 6) Revise the Blacklands Scout School.
- 7) Use a degree-day model for pecan pests.
- 8) Continue to predict boll weevil emergence with traps.

Year 3 — 1983

- 1) Implement personnel requirements.
- 2) Make greenbug resistant wheat available to producers.
- 3) Implement Moth ZV3 and boll weevil predictions.
- 4) Provide a prediction model for pecan pests.
- 5) Continue to evaluate items 6 through 10 of Year 1.

Year 4 — 1984

- 1) Begin a modeling program for small grain production.
- 2) Evaluate tropical adapted sorghum lines for Blackland production.
- 3) Evaluate new compounds.
- 4) Continue to evaluate items 6 through 10 of Year 1.

Year 5 — 1985

- 1) Achieve economic management of boll weevils and *Phymatotrichum* root rot.
- 2) Evaluate new compounds.
- 3) Continue to evaluate items 6 through 10 of Year 1.

Research Needs

COTTON:

Successful education programs depend upon strong and well designed research. Additional personnel are needed to work in program areas previously neglected.

Early cotton varieties should be evaluated. Improved lines will be needed to enhance the yield potential of cotton from Blackland soils. Important aspects of this research include: 1) host plant resistance within agronomic varieties; 2) development of plant types suitable for stripper harvest; 3) understanding the interaction of cotton variety and early season control; and 4) the need for suitable cotton desiccants that can substitute for arsenic acid. Variety selection should also be extended to sorghum production to reduce the need for insecticides.

Pesticide evaluation for the control of target pest species should be expanded. Researchers are urged to look for new classes of compounds which possess a greater selectivity in the crop ecosystem. Insecticides which are effective but have a short residual are desirable for use in integrated pest management programs for cotton and sorghum.

Research should develop a growth terminating chemical for use with defoliants. A chemical of this type would eliminate the plant regrowth problem which occurs after producers have stripper harvested their cotton. The termination of plant growth after harvest would decrease the food supply for potential overwintering boll weevils, and greatly aid in cultural control strategies.

Information on the overwintering habitat and survival of the boll weevil is needed. The development of remote sensing techniques should aid in understanding the overwintering habits of this major pest. Boll weevil movement during the fall and spring, and the

factors which trigger the movement of boll weevils into overwintering quarters, must be defined. Proper timing of fall insecticide applications for boll weevil control must be established. The use of other control methods may reduce the need for fall sprays. Diapause occurrence in the populations must be correlated to overwintering survival the following spring. Additional work will be needed to establish boll weevil response to pheromone traps, and to determine if pheromone can be used as a trapping system in the spring when community-wide populations are low. Growers need a life table for the complete seasonal and overwintering habits of this pest.

Research on the manipulation of early season insect populations in the cropping system also is needed.

SORGHUM, SMALL GRAINS, PEANUTS AND PECANS:

The Texas Blacklands is an intensive agricultural area which, in general, is ecologically diverse. Grain sorghum (1,370,900 acres) and small grains (1,304,700 acres) constitute major crops in this unique production area, but related entomological research has essentially been lacking.

Research is urgently needed to identify and evaluate components of sorghum and small grains pest management applicable to Blacklands crop production. The close association of the pest and beneficial species needs to be assessed so that maximum use of beneficials can be made.

Insect resistant small grain and sorghum germplasm has been identified from existing research programs; however, these varieties need testing and evaluation under Blacklands pest and environmental conditions. Recent discoveries of greenbug resistant sorghums and small grains, and sorghum midge resistant sorghums, could have far reaching effects on Blacklands pest management systems.

Sorghum breeding programs based at College Station and Lubbock are providing new germplasm selected for greater adaptation. These new sorghum types could greatly increase sorghum production in the Blacklands area.

In recent years, yellow sugarcane aphid populations in sorghum have increased. Little is known about this pest. A greater understanding is urgently needed of the aphid's biology, population dynamics and damage potential.

Insecticides are an important part of pest management. However, sound integrated control strategies are needed to circumvent the insecticide resistance problem encountered with the greenbug in other areas of the state. Insecticides must be relied upon to control such pests as the sorghum midge in late planted sorghum until resistant varieties can be improved agronomically. Research is needed to develop insecticide use techniques that are applicable to sound pest management systems. For example, insecticide use should be based on actual need instead of preventative treatment. The advantages and disadvantages of applying applications of systemic insecticides must be

determined. Also, the influence that insecticide treatment to one crop has on other crops in the ecosystem, especially regarding beneficial insects and release of secondary pests, requires investigation.

The recently established entomology research position at the Texas Agricultural Experiment Station at Dallas should be designed to conduct some of the needed research, in particular, studies of the association of pest and beneficial species in sorghum and cotton.

Additional research on pest resistant varieties and the yellow sugarcane aphid should be conducted at the Temple station. A research associate with project leadership from Dallas or College Station could have this responsibility.

Research objectives for sorghum, small grain, peanut and pecan programs are as follows.

SORGHUM AND SMALL GRAINS:

- 1) To investigate the interchange of pest and beneficial arthropods between cotton and other crops — especially sorghum, small grains and grasslands.
- 2) To evaluate greenbug resistant small grains.
- 3) To evaluate sorghum midge resistant sorghums.
- 4) To investigate the influence of pest resistant varieties on other crops in the ecosystem.
- 5) To conduct biological, ecological and damage assessment studies of the yellow sugarcane aphid, greenbug, lygus bug and chinch bug.
- 6) To determine the development of the biotype E greenbug.

PEANUTS:

- 1) To increase research on *Pythium* pod rot and leaf-spot resistant peanut varieties.
- 2) To search for biological control organisms and study the nontarget effects of fungicides.
- 3) To study the economic impact of potato leafhopper on runner type peanuts.
- 4) To continue studying biological control of cotton bollworm.

PECANS:

- 1) To develop economic thresholds for key pecan pests (pecan nut casebearer, pecan weevil, hickory shuckworm, pecan aphids). This requires development of sampling regimes, predictive modeling and research-extension-grower-industry cooperation.
- 2) To reduce plant stress factors that cause alfatoxin problems in farmers' stock plants.
- 3) To develop additional pesticides for use against pecan arthropods, especially the pecan weevil.
- 4) To develop and refine ancillary technologies in meteorology, dendroecology and aerial photography to assist in modeling of pecans.
- 5) To develop a plant model to be used in studying various arthropods.

Program Evaluation

Continuous program evaluation will pinpoint program directions and needed changes. Evaluation will be initiated by the county specialist with the pest management steering committee. Frequent consultations with growers is mandatory to ensure desired goals and operations are being followed. Routine economic evaluations using conventional methods such as questionnaires, group comparisons, surveys, individual contacts and field observations will be conducted.

Unit evaluations will be the primary responsibility of the county staff. Regional evaluations will conform to statewide procedures as programs develop.

Regulatory Needs

Regulation of cultural control practices should be considered for the benefit of the program. Such regula-

tions may be politically controversial; therefore, strong producer leadership will be needed to get cultural practices adopted. A cut-off planting date for cotton in the spring should be seriously considered. A plow-up time and stalk destruction program must be made mandatory, but will be dependent on the weather conditions during the production season. This harvest schedule can be adjusted if diapause boll weevil applications are applied when needed.

A regulation to require the prompt destruction of fields for which farmers will receive payments by the ASCS probably is required. Stalk destruction and plow-up must be done before these abandoned fields can add to the area-wide boll weevil population.

EAST TEXAS PEST MANAGEMENT PLAN

The agricultural commodities of cotton, soybeans, sorghum and small grains, and the expansive pine forests, lend themselves to the development of integrated pest management programs in East Texas. The success or failure of a pest management program in East Texas will depend on producers' acceptance and implementation of: 1) advanced scientific technology; 2) changes in cultural practices; 3) new crop varieties; 4) newer and better ways to apply fertilizers; 5) new uses of chemical weed control; and 6) scientific use of insecticides developed by research and demonstrations. The acceptance of such changes can be enhanced by an effective educational program.

In 1979 there were approximately 25,900 acres of cotton planted in the East Texas area, the majority in Lamar, Delta, Bowie and Houston counties. The dominant variety of cotton in the northern part of the area was Lankart-57; in the southern part of the area it was Stoneville 1633.

Soybeans and small grains have increased dramatically in this area in the last few years. If the prices of these crops continue to hold steady, cotton will not increase in the area because of the economics of production. More than 100,000 acres of soybeans and 70,000 acres of small grains were planted in 1978. These acreages are expected to increase in the next few years. These crops are grown for winter forage for livestock as well as for grain. Sorghum will continue to be grown in this area and, in some cases, it will be double-cropped with soybeans.

East Texas' commercial pine forests occupy more than 11 million acres and contribute billions of dollars to the state's economy in the form of raw materials and finished wood products. The increased world-wide demand for wood and wood products has focused considerable attention on the South in general, and Texas specifically, as a source of pine timber. By virtue of their acreage alone, East Texas pine forests represent the single most important commodity in this region of the state.

Cotton is planted from mid-April to late May. Cotton harvest starts in late September and usually terminates in November. In some years, when the weather does not allow for early harvest, the season may extend into January. Producers in Lamar and Delta counties treat early for thrips, fleahoppers and boll weevils, but rarely use late season control programs because of low production potential. Production in these counties is much like the Blacklands area cotton production sys-

tem because of the similar cotton varieties grown and the similar soil types.

Soybeans are planted in late May or early June. Most soybeans are harvested in October and November. Sometimes soybeans are double-cropped with small grains.

Unlike agricultural crops, pine stands are rotated over many years depending upon the end products—for example, timber or pulp wood. The shortest rotation is generally 20 years.

The implementation of a total pest management program on all crops could show great economic returns in this area.

Damage from boll weevils, cotton fleahoppers and tarnished plant bugs is a major factor in the decrease in cotton acreage. Many producers in the area simply plant cotton and hope that it will make a decent yield with very little use of insecticides, fertilizers, weed control, etc. It has been estimated that 25 percent of the cotton producers do not carry out an adequate early season control program. And very few farmers apply insecticides late in the season because of the lack of potential cotton yield.

No mandatory plow-up date for pink bollworms exists in this area. Cold weather normally kills most pink bollworms if they remain on the soil surface. Cultural practices alone have kept the pink bollworm a minor pest.

Most soils require fertilizer to produce highest yields. Nitrogen requirements range from 40 to 60 pounds per acre. Excessive nitrogen produces excessive growth, thus increasing the probability of bollworm/budworm outbreaks in cotton. Phosphate requirements range from 40 to 60 pounds per acre. A soil test will help determine the fertilizer requirements. Some producers are beginning to plant fast growing, short season cotton varieties. As newer varieties are developed by research, they should be demonstrated to producers.

Insecticides to control cotton fleahoppers and tarnished plant bugs should be selected carefully so as to leave as many beneficial insects as possible in the field to help reduce destructive populations of bollworms and budworms. When late season bollworm infestations occur, biological control should be augmented with microbiol (bacteria and virus) insecticides.

Cotton harvest should be started and completed as early in the fall as possible. Plant stubble should be cut

and plowed out immediately after harvest to prevent regrowth. This helps to lower the overwintering boll weevil populations in the fall, and reduce the buildup of pink bollworms.

Sorghum should be planted as early in the spring as possible. This helps the sorghum to pass through the blooming stage before heavy infestations of midge invade the area. Greenbug resistant varieties of sorghum should be planted. Crop rotation should also be used to reduce weeds and soil insect problems.

Soybeans have the greatest potential of all crops grown in East Texas for increases in acreage. The acreage will increase if new varieties become available that are climatically adapted to this area. The domestic and export markets for soybeans continue to grow.

Research on soybean insect control is deficient. As the acreage increases, insect problems are also expected to increase. The three-cornered alfalfa hopper causes damage throughout the area, and more needs to be known about economic thresholds, population dynamics, effective methods of detecting damage and effective control methods. A number of stink bugs feed on the soybean, including southern green stink bug (*Nezara viridula*) and green stink bug (*Acrosternum hilare*). Foliage feeding insects which occur include: soybean looper (*Seudoplusia insuldens*); cabbage looper (*Trichoplusia ni*); velvetbean caterpillar (*Anticarsia gemmatilis*); green cloverworm (*Plathypena scabra*); corn earworm (*Heliothis zea*); blister beetles (*Epicaula* spp.); and cucumber beetles (*Diabrotica* spp.). As some foliage feeding insects also feed on the pod, damage may be compounded. Basic information on detection techniques and economic thresholds would result in more efficient use of pesticides.

Weeds cause an estimated 15 percent reduction in soybean yields per year in Texas. Although many farmers use herbicides, they do not completely understand the difference in susceptibility of weeds to different herbicides. Specific herbicides only control a limited number of weeds. Soybean farmers need to use post-directed weed control more extensively since certain weeds may not be controlled with soil applied herbicides.

Some weed species are becoming more prevalent, such as: red weed (*Melochia corchloifolia*); morning-glory (*Ipomoea* spp.), hemp sesbania (*Sesbania exaltata*); and dwarf musk melon (*Cucumis melo*). They are becoming wide-spread because some are difficult to control with available herbicides. Although others can be controlled with herbicides, farmers do not fully understand proper application techniques. Although most growers use some type of herbicide, in many instances they are neither using the correct chemical nor using it properly. Farmers should be given information concerning the types and extent of weed infestations, and recommended practices for weed control.

Soybean diseases reduce yields in Texas by an average of 15 percent each year. Disease development depends on several factors such as varieties, cropping practices, temperature and moisture. Currently, the most economically damaging soybean diseases are anthracnose (*Collectotrichum truncatum*), pod and stem blight (*Diaporthe phaseolorum* var. *sojae*) and

Cercospora sp., which causes purple seed stain and premature defoliation. Several states have developed a point system to determine if foliar fungicide applications are necessary. This system has not been evaluated in Texas.

Planting of small grain takes place from September through December, with harvest in late May and early June. Insects such as fall armyworms, greenbugs and winter oat mites are considered problems. However, infestations of these insects vary from year to year. The introduction of the Hessian Fly into Texas poses a threat, as this may be a difficult pest to deal with. Losses from small grain diseases such as powdery mildew, rust, smut and septoria leaf disease can be reduced by selecting resistant varieties and using proper seed treatments. Winter weeds continue to be a problem in many areas where small grain is grown. Timely application of chemical controls can reduce the amount of damage these weeds cause.

Much of the small grain grown in Texas is intended for grazing. Producers who fertilize their small grain for a grazing program, and then are unable to graze the grain because of weather conditions, are likely to have more disease and insect problems. Weather conditions may cause the loss of nitrogen and, in some cases, necessitate the application of nitrogen for grain and forage production.

The pine forests are threatened by insect pests during every stage of tree growth. An IPM effort on all these pest problems is beyond the scope of our current programs, and those of the immediate future. However, extensive efforts have been underway during the last decade to develop effective management techniques to combat the state's most serious forest insect pest, the southern pine beetle. The southern pine beetle attacks and kills almost all ages of pines, but it is most damaging to mature and over-mature stands. The rather temperate Texas climate has enabled the beetle to develop up to eight generations a year. As a result it constitutes a serious threat for approximately 8 months of the year.

Proposed Program Strategy

COTTON:

A major objective of a pest management program should be to increase producers' net returns by helping to reduce losses from insects, weeds and diseases. This can be accomplished through the use of improved crop varieties, crop modeling techniques, modified farming practices (such as narrow rows), modified planting dates where needed, and improved chemical weed control and fertilization.

Cotton should be planted as soon after the last spring frost as possible. In the southern part of the area that date is between April 1 and April 15, and in the northern part it is from April 15 to no later than May 1. Early planted cotton consistently produces higher yields and has less insect damage than late planted cotton. All cotton should be up and to a stand by May 25.

Some producers are beginning to plant rapidly fruiting, short season cotton varieties. The number of acres planted in such varieties is expected to increase in the next 5 years.

Early Season Pest Management

Chemical control of thrips is rarely profitable. Cotton fleahopper and tarnish plant bug populations vary from year to year. When careful sampling indicates that these pest species exceed economic threshold levels, control measures should be initiated.

Mid-Season Pest Management

Cotton fleahoppers and tarnished plant bugs may be a problem in mid to late season. If these insects require chemical control, insecticide selection and rate of application are critical in preventing destruction of beneficial insects. Native populations of beneficial insects usually will maintain bollworm and tobacco budworm populations below economic threshold levels, except where broad spectrum insecticides reduce or eliminate these valuable natural control agents. Thus, the primary objective in managing bollworms and tobacco budworms should be to eliminate the use of broad spectrum insecticides except where careful sampling indicates they are required to prevent economic losses. Other mid-season pests should be monitored and controlled when necessary.

Late Season Pest Management

Producers should be encouraged to plant cotton early and use early maturing, short season varieties that can be harvested by September 15. This allows time for destruction of cotton stalks before large numbers of boll weevils are able to enter overwintering sites. Using these varieties also reduces the amount of insecticides needed and, in many cases, eliminates the need for fall and spring boll weevil control programs. These practices are much more effective if followed on a community wide or county wide basis.

If a mid- to late-season cotton insect control program is initiated, growers should consider using synthetic pyrethroids, viruses or microbials to control bollworms and tobacco budworms. Ovacides should be used when egg deposition is increasing and insect populations are of sufficient number to warrant control.

Weed Control

Johnsongrass and many other grasses are considered to be quite a problem. Some of these other grasses can be controlled with preemergence herbicides, while Johnsongrass can be controlled with post-emergence herbicides. The timing and dosage of herbicide applications should be demonstrated at selected county locations.

Controlling cotton root rot is still a problem on Houston clay soils, and additional research is needed. Rotating cotton with other crops, and also from field to field, helps reduce losses from this disease. Cotton varieties resistant to bacterial leaf spot and to bacterial wilts should be selected whenever possible.

SORGHUM:

Sorghum should be planted in the month of March as soon as weather conditions allow. Early planting ensures that it will bloom by June 25 to escape midge damage. Sorghum should be watched very closely for early populations of greenbugs about the time it emerges from the soil. Planting greenbug resistant varieties helps reduce the need for insecticides.

The pest management program should demonstrate the value of planting sorghum early; this could be done through educational programs and demonstrations. The importance of greenbug resistant sorghum varieties should be stressed to seed dealers and leading producers, and mass media used to show the advantages of these varieties. Greenbug resistant hybrids are vulnerable in early growth stages before the resistant trait manifests itself. Economic thresholds should be developed for this early growth stage.

The effectiveness of midge resistant hybrids should be determined. A chinch bug survey should be conducted to determine the effects of winter weather on the survival of overwintering populations. Surveys should be conducted throughout the area to determine how damaging the sugarcane root stock weevil is, and its relation to lodging and charcoal rot.

Growers should be urged to plant disease resistant varieties and use appropriate weed control techniques.

SOYBEANS:

The integrated pest management objective for soybeans is to help producers incorporate all sound pest management procedures. Program data should be interpreted to producers who cooperate in demonstration programs. Insects, diseases and environmental conditions should be monitored weekly during periods of peak insect and disease occurrence so that producers will have advance knowledge of potentially damaging situations. Variety test plots should be grown to demonstrate the capabilities of new varieties. New techniques in weed control also should be demonstrated.

SMALL GRAINS:

Demonstrations on small grains for both forage and grain production should continue. New programs should demonstrate the advantages of various seeding rates and planting times on forage production, and the importance of insect and disease resistant varieties. Surveys are needed to determine the extent of Hessian fly infestations in the area. Information gained in these surveys should be presented to producers in educational meetings, through mass media and via personal contacts. Seed dealers, agribusiness personnel and others interested in growing small grains should be made aware of all programs.

PINE FORESTS:

Forest entomologists at Texas A&M University, in cooperation with the Texas Forest Service, USFS and

industry, are developing techniques for managing the Southern pine beetle. As a first step, existing information on population dynamics, host dynamics, treatment tactics, etc., is being compiled and evaluated. The end result will be a system whereby forest managers can achieve specific goals such as detecting, controlling or preventing southern pine beetle attack.

Program Organization and Extension Needs

Area grower associations should have representatives from each trade community to act as a governing board for pest management programs within their areas. This board could collect and distribute monies for crop scouts, forward funds to TPMA for proper distribution, act as an advisory board to determine what fields should be scouted within a county, help in recruiting scouts, and help in directing future research needs.

Extension agents-entomology (PM) are needed in Greenville, Texas to work with cotton producers in Hunt, Delta and Lamar counties, and in Red River or Bowie county to work with cotton, soybeans, sorghum and small grains pest management programs. A third county position could be established in Houston County to work with cotton and small grains. And an area Extension entomologist-pest management could be stationed in Overton to coordinate IPM activities in that area. He would be responsible for assisting county pest management programs and developing educational materials and forms necessary to carry out the programs. He could work with Extension specialists in that area on educational programs, preparing information on insect sampling, television programs and mass media releases. With appropriate Extension specialist supervision, county pest management personnel could conduct demonstrations in weed control, new varieties, fertilizer management and other practices.

A weed control specialist stationed in Overton, Texas would be an effective addition to the Extension staff. This person should be responsible for demonstration work on weed control in small grains, soybeans, cotton and sorghum. He would assist the county pest management programs with specific information on weed control.

Research Needs

One additional research agronomist is needed in Overton to work on weed control and new varieties for the four crops grown in this area. Research is needed on the following: 1) the source and colonization time of cotton by key insect predators; 2) evaluation of the effectiveness of native predators and parasites of the boll weevil, bollworm, tobacco budworm and plant bugs; 3) the economics and efficiency of a fall diapause program; 4) factors responsible for the emergence and colonization of cotton by the boll weevil; 5) efficient

ways of distributing preemergence herbicides, fertilizers and pesticides; 6) improved soybean varieties adaptable to growing conditions in East Texas; 7) chemical control of soybean diseases; 8) the effects of seed treatments on soybeans, sorghum, cotton and small grains; 9) more profitable crop rotation systems using soybeans, cotton, small grains and sorghum; 10) improved cotton varieties; 11) cultural practices necessary to reduce sorghum pest populations; 12) sorghums resistant to greenbug, chinch bug and midge; 13) the role of arthropods as vectors of sorghum disease agents; 14) improved small grain varieties for forage and grain production; and 15) escaped weeds that are not killed by preemergence herbicides.

Resistant variety studies should be initiated for all four crops in this area. An evaluation of new desiccants and defoliants helpful in producing an early harvest is needed. These desiccants and defoliants could be used on sorghum, cotton and soybeans. Research on the use of selective insecticides on cotton, sorghum and small grains should continue. Computer modeling of insect, disease and weed problems on all four crops should be studied. Detailed work on the Moth-ZV3 model should continue in order to validate the productive capabilities of this model in the East Texas Pest Management Program. This model should be used to predict outbreaks of bollworms, tobacco budworms and lygus bugs in cotton.

The Hessian fly, a potentially dangerous insect, has recently been introduced in small grain fields in the north central part of Texas. Research needs to be done on the effects this insect might have on small grain production in northeast Texas. It is recommended that a plant pathologist be stationed at Overton, Texas to assist in disease control work on soybeans, small grains, cotton and sorghum.

Program Evaluation

Crop budget analysis will be used to compare the cost/benefit relationship of the proposed IPM system with conventional practices.

Regulatory Needs

Cotton producer organizations should call for a referendum on mandatory fall deadlines for cotton stalk destruction. Cotton in the southern part of the region should be destroyed and plowed under no later than November 30. Present research indicates that fall stalk plow-under is not needed to control pink bollworms in the northern area. The enforcement of destruction dates should be the responsibility of a board made up of local cotton producers. This board should have the power to set fines or to withhold cotton from sale until the crop is destroyed, as well as the authority to set a spring planting deadline.

Should future research indicate that mandatory fall planting dates for small grains are needed to control the Hessian fly, such regulations may become necessary.

CENTRAL TEXAS RIVER BOTTOMS PEST MANAGEMENT PLAN

The Central Texas River Bottoms area includes 18 counties. Through this area flow the San Antonio, San Marcos, Guadalupe, Colorado, San Gabriel, Nava-sota, Brazos and Little rivers. In 1979 this area had 141,100 harvested acres of Upland cotton. This was 2.07 percent of the state's total production. Approximately 8,200 acres of cotton in this area are irrigated. The remaining are in dryland production. The area's average 452 pounds per acre lint yield is more than the state average. However, the average lint yield for the irrigated acreage ranges from 700 to 900 pounds. Sorghum was planted on 239,000 acres in 1979, and very little grain sorghum in this area is irrigated.

Much of Milam, Williamson, Travis, Caldwell and Guadalupe counties has Blacklands soils. A certain percentage of cotton and grain sorghum grown in these counties, even though not irrigated, is produced on bottom lands and responds to high rainfall and cultural practices in much the same as the irrigated cotton.

Most of the irrigated acreage is in the Brazos River bottom. The irrigated acreage is geared to higher production, and in these areas a completely different cropping system is practiced. Slower maturing cotton varieties are planted and production costs are increased by irrigation, additional fertilizer and increased insecticide usage.

The development of resistance in the major cotton insects has rendered obsolete all of the chlorinated hydrocarbon chemicals that were once effective. The insecticides presently used are organophosphates. These short-lived materials are not as effective as the chlorinated hydrocarbons once were, and usually must be applied as often as every 5 days. The tobacco budworm has developed a high level of resistance to these compounds. Tobacco budworms typically reach damaging levels by August. Rank, succulent cotton in the late summer is highly attractive to this pest. 1978 estimates indicate that insects destroy approximately 23.0 pounds of lint per acre.

When grain sorghum is planted at the optimum planting date, little or no insect damage occurs; however, late planted sorghum is often damaged by sorghum midge or sorghum webworms. Many producers in this area are following pest management programs recommended by the Texas Agricultural Extension Service. A supervised pest management program using a county Extension entomologist is operating in Williamson and Milam counties. During the 1980 growing season, this program included 6,500

acres of cotton. The program has made producers aware of the benefits of proper pest management techniques, and demonstrated the benefits of an effective scouting program. Over the next 5 years, the acreage in the program should decrease as producers become aware of the values of pest management, and efforts are directed to other pest management educational opportunities. Producers should be encouraged to employ consultant entomologists or qualified field scouts. This type of pest management program will increase production and reduce production costs. From 65 to 90 professional field scouts could be employed in this area.

Proposed Program Strategy

COTTON:

Cultural practices used in the Central Texas River Bottoms should encourage early plant maturity and early stalk destruction. Producers in this area are planting as early as possible in most instances, and are aware of the problems associated with late planted cotton. Although early planting may increase the survival of overwintered boll weevils and encourage early infestations, this disadvantage is offset by the increased weevil mortality in the fall due to early destruction of crop residue.

It is also important that sorghum be planted early, as heavier populations of midge and sorghum webworms have been found to occur in late planted sorghum. Insecticide drifting from sorghum fields often reduces the number of beneficial insects in cotton, thus increasing the damage from bollworms and tobacco budworms normally controlled by these natural enemies.

Reducing irrigation and nitrogen fertilization increases the chance for earliness in any of the commonly grown indeterminate Delta varieties of cotton. However, during prolonged periods of rainy, cloudy weather many of these cottons become vegetative with considerable delay in fruit set.

The TAMCOT SP varieties are much less sensitive to unfavorable weather, and will maintain rapid fruit set even when fruiting is delayed in other varieties. Because of their uniformity of fruiting from one year to the next, TAMCOT SP varieties are more appropriate than other varieties for a pest management system in the Central Texas River Bottoms.

The experience of the last 10 years suggests that full season irrigation of cotton in the 40-inch rainbelt of Texas is not a realistic practice. Although the months of July and August are usually dry, many times they are wet. Vagaries of weather can add random, untimely amounts of water on full season irrigated cotton. This can delay fruit set, prolong fruiting and destroy the chances for early harvest.

If irrigated cotton is grown in the 40-inch rainfall area, irrigation should be limited to a single watering prior to July 15. Rainfall data from 1943 to 1974 for the period July 12 to August 8 shows that 2 or more inches of rain fell in the area in 15 of the 30 years. Thus, rainfall usually supplies some or all of the water normally applied in a second irrigation. In years that abundant rain occurs in June and July, no irrigation is needed.

There is considerable evidence to indicate that a single irrigation cotton system reduces insect attack. If so, insecticide use could be reduced and probably eliminated in many cases. Cotton could be harvested earlier, stalks destroyed promptly and land prepared for the next year's crop during the fall rather than winter months.

Commercial fertilizers have increased cotton yields significantly in the Central Texas River Bottoms, however, excess amounts are being used in many instances. Adding large amounts of nitrogen encourages excessive vegetative growth. This, in turn, provides a habitat for injurious insects and pathogenic organisms which rot bolls, and also has a tendency to delay harvest and stalk destruction.

Coupled with restricted use of irrigation water, fertilizer used could be dropped to 40 to 50 pounds of nitrogen and 0 to 20 pounds of phosphorus per acre annually, as recommended by agronomists. This would reduce fertilizer costs by about \$35 to \$50 per acre. At this low rate of nitrogen use, potassium rarely would be required.

Insect control is important to cotton production in the Central Texas River Bottoms area. Producers must not only control cotton pests, but also maximize profits. To do this, production costs must be lowered while yields are maintained. The key to this seems to lie in *early harvest* and in proper management of early season pests.

Early Season Pest Management

Proper management of early season pests and boll weevils is crucial to the overall pest management program, as insecticides used for the control of these pests often encourage bollworm and budworm problems later. Early season insecticide applications, if improperly timed, disrupt the beneficial insect populations in cotton fields. Chemical insecticides should never be used unless pest populations exceed the economic threshold level.

Large numbers of thrips, aphids, leaf miners and cotton fleahoppers can delay the crop. However, these pests are also important food sources for predaceous insects that are needed later in the growing season to help suppress bollworm/budworm numbers. As a rule there are no effective management tactics for control-

ling these pests except dependence upon natural predators and parasites and the use of chemical insecticides. Thus, producers must carefully decide whether control is necessary, what chemicals should be used at what dosage rate, and when chemical applications should be terminated to ensure the maximum buildup of beneficial insects before damaging numbers of bollworms/budworms appear. A professional entomologist should be used to determine the probabilities of economic damage and recommend the most economical and effective control measures. Decisions to spray chemical pesticides for early season pests should be based not only on the numbers of pests present, but also upon some index of pest damage.

The cotton fleahopper and lygus bugs can be the most serious cotton pests during the early fruiting period until the first blooms appear, a period of about 3 weeks. Spraying for the cotton fleahopper should be considered only when both fleahopper numbers and damaged squares exceed economically damaging levels.

Intensive sampling for overwintered boll weevils should be conducted before the first 1/3 grown squares appear. If a single adult weevil is found, or if 10 percent of the small (less than 1/3 grown) squares are damaged, then one or two applications of insecticide may be needed. These treatments must be made before 1/3 grown squares are available to prevent egg laying. Insecticide treatments should be applied only to fields or parts of the field that are infested. Excessive insecticide use may reduce beneficial insect numbers to such low levels that they are unavailable to help control bollworms/budworms.

Mid-Season Pest Management

Chemical control of all cotton insect pests should be avoided, if possible, during the mid-season, i.e., from first bloom until first hard bolls. Most insecticides effective for boll weevils and bollworms/budworms also destroy beneficial insects and spiders. Thus, insecticide resistant tobacco budworms are released from natural control and can cause extensive damage.

Insecticidal control of the boll weevil should be initiated when 15 to 25 percent of the squares are damaged. Insecticides should be applied for bollworms/budworms only if 15 to 25 percent of the green squares are worm damaged. Specific recommendations for the control of these pests may be found in *Suggestions for Managing Cotton Insects*, published by the Texas Agricultural Extension Service.

Sorghum should be inspected frequently for damaging insects, and insecticides applied only when needed. Precautions should be taken to avoid drift over cotton and other sorghum fields.

Late Season Pest Management

Early destruction of crop residue must be emphasized as a means of controlling pink bollworms and boll weevils. In addition, fall insecticide applications can greatly reduce overwintering boll weevils. An effective program would be to apply an insecticide with the desiccant, and continue to apply insecticide at 7- to 10-day intervals until the crop residue is plowed out.

This has been shown to reduce the overwintering boll weevil population by about 80 to 85 percent.

Program Organization and Extension Needs

There is no strong producer organization in the Central Texas River Bottoms area. Producers might benefit from such an organization; however, mass media and Extension programs could adequately inform them of pest management practices. A great deal of emphasis should be placed on the modification of cultural practices. Producers should be encouraged to consult qualified entomologists for help in making insect control decisions. Several consulting entomologists are presently employed in this area. Their value to the cotton farmer has been well established.

The Texas Agricultural Extension Service should conduct county meetings which expose cotton farmers to the biology, distribution, habitat, field identification, scouting techniques and control of key pest species. Points to be taught should include alternatives to chemical control, the value of beneficial insects, variety selection, planting dates, termination dates, proper destruction of crop residue, diapause boll weevil control and other agronomic practices which affect insect populations and their control. Production guidelines should be given to producers and other cotton interest groups. Training and technical guidance to commercial insect scouts should be provided throughout the year by way of insect scouting schools and workshops. Newsletters should be available to all cotton growers in the area, with information on insect population trends, scouting techniques and forecasts of future pest outbreaks. As in the past, the Texas A&M University Plantation and cooperating producer farms should be used as sites for pest management demonstrations, meetings and field days. Timely news releases on a regional basis, and circular mail from the county Extension agent's office, can further convey pest management information.

Research Needs

Many research needs must be met if we are to maintain progressive and effective pest management programs in Texas. Research objectives should include:

- 1) To develop improved sampling techniques for overwintered boll weevils to prevent excessive early damage and excessive use of expensive chemicals.
- 2) To incorporate boll weevil, bollworm, fleahopper and disease resistance into a short season, rapid fruiting cotton variety.
- 3) To develop new economic thresholds for applying insecticides to these cottons should they be attacked by certain pests.

- 4) To develop a glandless cotton variety with high quality protein edible (without extensive chemical-physical processing) for humans and nonruminant animals, and that has sufficient insect resistance for profitable Texas production.
- 5) To develop optimum planting patterns, fertility rates, irrigation schedules and suitable machinery for producing these new cottons. (A new production system may have to be devised for these varieties.)
- 6) To develop new biological control agents for the principal insect pests of cotton and grain sorghum, including parasites, predators and insect pathogens. A new research program will be initiated on the use of insect viruses to control the caterpillars that feed on these crops.
- 7) To evaluate the efficiency of native predators and parasites, and establish predator-prey ratios to use in pest management programs.
- 8) To further define computer simulation techniques for forecasting insect outbreaks and predicting crop yields.
- 9) To use the latest techniques of systems science and economic analysis to evaluate new pest control strategies and optimize production practices for maximum profits.
- 10) To evaluate sorghums resistant to greenbug and sorghum midge.
- 11) To determine economic injury levels of major sorghum pest species.

The ultimate research goal will be to completely rebuild the cotton industry in Texas with pest resistant varieties adapted to each of our major production areas.

Program Evaluation

A pest management program of this type should be evaluated from the following aspects:

- 1) Effectiveness in controlling cotton insect pests. This could be accomplished through surveys and general observations over a period of several years.
- 2) Effect on yields. This would be available through normal reporting agencies, local gins, producer records and result demonstrations.
- 3) Economic impact. This would include the costs of all pest management and production strategies in relation to economic returns.
- 4) Environmental impact. This should include factors such as effects on nontarget organisms and human health, and resistance of target organisms.
- 5) Energy use. Possible reduction of fertilizer, water and insecticides will affect the total energy used.

Regulatory Needs

Regulated planting and plow-up dates to suppress boll weevil and pink bollworm should be stressed.

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UPPER GULF COAST PEST MANAGEMENT PLAN

The Upper Gulf Coast differs from other production areas of Texas because of its high annual rainfall of 36 to 56 inches. This rainfall, along with the area's moderate temperatures, results in nearly ideal conditions for arthropod pests, weeds and diseases of cotton, sorghum, rice and soybeans.

Cotton is produced on about 115,000 acres and grain sorghum on 409,000 acres in this 17-county area. Only 4 percent of the cotton and 1 percent of the grain sorghum is irrigated. Thus, irrigation is not a major component of production systems. Other factors, such as planting and harvesting dates, can be managed to provide cultural control of key pests. Examples are early cotton stalk destruction for boll weevil, bollworm and pink bollworm suppression, and optimized planting dates for sorghum midge control. Key phenological events of both crops should be considered as they relate to movement of predators and parasites between crops. Other factors such as fertilization rates, herbicide choice, seedling disease control, nematode control and choice of cotton and grain sorghum varieties can be managed so as to preserve a clean environment while providing maximum profits for producers.

Cotton and grain sorghum dominate the southern portion of the Upper Gulf Coast, while rice and soybeans dominate the upper portion. Rice and soybeans are often grown on a rotation basis, and the majority of producers may raise both crops. Approximately 550,000 acres of rice and 450,000 acres of soybeans were grown in the area in 1979. The rice acreage is expected to remain stable because of world demand; however, soybean acreage is increasing.

COTTON:

Diseases

The major diseases causing economic loss are the seedling disease complex, *Phymatotrichum* root rot, bacterial blight, boll rot and the *Fusarium* wilt-root knot nematode complex. These diseases reduce yields by about 20 percent annually. In addition, diseases disrupt management plans and increase production costs. For example, seedling disease may necessitate replanting the crop, and disrupt a short season production plan. In cases where stands are adequate, roots damaged by seedling pathogens cause plants to be less efficient in using water and nutrients, which leads to delayed maturity. Losing a high percentage of a bottom crop to boll rot may force producers to

extend the season to set a top crop. This would add insect control costs. Crop rotations for reducing losses caused by root rot and wilt-nematodes may prevent optimum use of land in a total crop management plan.

Insects

Most of the cotton producing area of the Upper Gulf Coast has only a 10 or 20 percent chance of getting 4 or more inches of rain during August, but in September the probability increases to 40 to 50 percent. Thus, if the cotton crop is not harvested before September, the risks are high that rains will delay final harvest and crop destruction until November or December. The presence of growing cotton plants after August greatly increases the probability of large numbers of boll weevils surviving the winter to cause damage to the next year's crop. Also, September rains are frequently responsible for yield reductions from boll rot and reduced lint quality. Thus, one of the keys to successful cotton production in the Upper Gulf Coast is to produce an early maturing crop that can be harvested and plowed under before September.

The boll weevil destroys about 1,478,824 pounds of lint each year in the Upper Gulf Coast area. This is about 2.7 percent of the total lint yield, or 9.0 pounds per acre. Total insect loss estimates are 7,394,432 pounds of lint each year. This amounts to 12.0 percent of the total lint yield, or 44.9 pounds of lint per acre. Insecticides are applied to 84 percent of the total cotton acreage at least once each year.

Advanced pest management systems have been demonstrated in the areas which show excellent potential for increasing yields and profits while decreasing insecticide costs and environmental pollution. Such a system was demonstrated on Texas Department of Corrections (TDC) farms in the Upper Gulf Coast area. The results emphasize the importance of careful insect sampling by qualified entomologists in making critical pest management decisions.

The TDC system consisted of techniques that could be used to manipulate the abundance of the three main cotton insect pests. In the case of the boll weevil, management was achieved by a combination of early stalk destruction, insecticide treatments in the fall for diapause control and spot treatments in the spring for overwintered weevils. Often a single, low dosage insecticide application was adequate to suppress fleahopper numbers below damaging levels. As a result, both boll weevil and cotton fleahopper management techniques

resulted in the conservation of natural populations of beneficial insects and spiders.

Tobacco budworms and bollworms were managed on the TDC farms by increasing the action threshold from 5 percent to 15 percent damaged squares and sampling carefully. As a result, insecticidal use for bollworms/budworms declined drastically and, in many years, no insecticides are needed for *Heliothis* control. The current action threshold for *Heliothis* is 15 to 25 percent damaged squares.

An economic analysis of the TDC program on the Brazos River area farms indicated that the new strategies reduced insecticide use from 12.9 pounds per acre to 6.4 pounds, and increased yield from 229 to 345 pounds of lint. About 50 percent of the lint increase was attributed to the pest management program. Estimated net returns increased from a loss of \$9.18 per acre to a gain of \$36.04 per acre.

Expanding this program to the 215,000 acres of the TDC study area could increase cotton output by more than 27,000 bales, reduce the quantity of insecticides applied by 1.4 million pounds, and increase net returns by more than \$5.4 million.

Weeds

Weeds are a major problem for Texas cotton producers. Uncontrolled weeds and grasses interfere with harvest operations, and grassy bales reduce grades. Pigweeds (*Amaranthus* spp.), Johnsongrass (*Sorghum halepense* [L.] Pers.), morningglory (*Ipomoea* spp.) and nutsedge (*Cyperus* spp.) are common problems. Other weed species which are increasing include lanceleaf sage (*Salvia reflexa* Hornem.), cocklebur (*Xanthium pensylvanicum* Wallr.), pie melon (*Citrullus vulgaris* Schrad.), smell melon (*Melothria pendula* L.), silverleaf nightshade (*Solanum elaeagnifolium* Cav.) and sunflower (*Helianthus* spp.).

It is estimated that in spite of present weed control efforts, weeds account for a 7 percent reduction in cotton yields annually. In 1977, this amounted to a loss of 382,550 bales in Texas.

Since the introduction of preemergence herbicides in the late 1950's and preplant herbicides in 1964, there has been a gradual shift in the predominant weed species from grasses to annual and perennial broadleaved weeds. Preplant incorporated herbicides satisfactorily control annual grasses, seedling Johnsongrass and certain small seeded broadleaved weeds, but not large seeded broadleaved weeds and rhizome Johnsongrass. Thus, these species are the main problems in most fields. Annual grasses compete with crops only when weather conditions prevent proper herbicide incorporation.

Certain broadleaved annual weeds are adequately controlled by preemergence herbicides, while others require directed postemergence herbicides or rotation to sorghum, corn or small grains in order that different herbicides can be used. Directed postemergence herbicides should be used more, but there is little equipment in the state. Over-top postemergence herbicides are used effectively, but often injure the crop when applied during periods of moisture stress.

The key to designing an effective weed control program is identification of problem species. Few producers are able to identify weeds that escape control with presently used herbicides. Weed mapping and record keeping can help identify problem areas that need special attention the following year. Prevention, crop rotation, and mechanical and chemical control must be integrated with other production practices to achieve maximum weed control and profits.

SORGHUM:

Diseases:

Sorghum is plagued by a variety of disease problems. These diseases vary in importance from year to year and from one location to another, partly because of environment, plant genotypes, cultural practices, variations in pathogens or the interaction of any of these factors.

One could say that, over the past two decades, sorghum in South Texas has been under microbiological siege. Head smut has long been a problem. Although resistant varieties were developed, the head smut pathogen was able to overcome this resistance. In 1966, producers experienced the first major epidemic of anthracnose. By 1968 it caused devastating losses. Although downy mildew was first observed in 1961, the first widespread outbreak of the disease occurred in 1967. Since then, attempts to control downy mildew have been directed primarily toward the development of disease resistant hybrids. Shortly after the advent of downy mildew, the occurrence of a widespread, aphid-transmitted virus became a major concern. This disease, maize dwarf mosaic, is an annual problem.

Leaf diseases also threaten crop production. While foliar diseases are usually more prevalent in wet years, major losses from charcoal rot and other stalk rots can be related to high temperatures and drought stress during the latter part of the growing season. Extensive moisture after grain has matured, as happened in 1976, can cause a microbial decomposition of the grain known as grain molding or weathering. This sometimes leads to sprouting and significant losses due to test weight and quality of the seed.

Other environmentally related sorghum diseases include nutritional disorders, waterlogging and high salt concentrations in the soils which result in poor growth and poor root development. Be it hot or cold, wet or dry, good season or bad, new variety or old, it is possible, even likely, that a damaging disease will develop.

Because of the wide variety of sorghum diseases in South Texas, no one strategy can prevent sorghum losses. Consequently, all types of disease control strategies must be considered.

Weeds

Weeds reduce yields, interfere with harvest operations and harbor insect and disease pests. The major sorghum weeds of this area include broadleaf signalgrass (*Brachiaria platyphylla* [Griseb.] Nash), brown-top panicum (*Panicum fasciculatum* var. *reticulatum*

[Torr.] Beal), crabgrass (*Digitaria* spp.), Johnsongrass (*Sorghum halepense* [L.] Pers.), junglerice (*Echinochloa colonum* [L.] Link), morningglories (*Ipomoea* spp.), pigweeds (*Amaranthus* spp.) and Texas panicum (*Panicum texanum* Buckl.). Others are problems in local areas.

Texas' losses due to sorghum weeds amounted to more than \$42 million in 1974. The main weed control practices are a combination of cultural (good seedbed preparation and cultivation and chemical (herbicides) methods. The primary sorghum herbicides are s-triazines which control broadleaf weeds but are weak on grass weeds; thus, grasses are the major problem in sorghum. Crop rotation can help in a weed control program. For example, rotating sorghum with cotton permits a good grass herbicide to be used in the cotton phase of the rotation to reduce the population of grass weed seed.

Producers need training in recognizing weed species so cultural, mechanical and chemical control programs can be designed for specific problems. As in cotton, weed mapping and record keeping should be integrated with other production practices.

RICE:

Rice is produced on approximately 550,000 acres in the Upper Gulf Coast Prairie of Texas. All of the rice acreage is irrigated, and almost all of it is flooded for most of the growing season. Producers use an integrated management system that includes not only pest management but also other aspects of production. For example, water management has an influence on planting method, nitrogen fertilizer efficiency, rice water weevil incidence and weed control. Thus, rice producers are familiar with the concept of integrated management.

Diseases

Disease losses in rice are estimated at 12 percent per year. Most suggested disease control techniques require changes only in cultural practices, or selection of a resistant variety at little or no extra cost. New techniques, including use of foliar fungicides, require proper disease identification and a history of disease incidence in fields to be profitable. Producers must select control techniques based on the most vulnerable point in the organisms' life cycle. Crop rotation controls some diseases, while seed treatments or foliar fungicides control others. Some disease problems are solved with proper fertilization, or by planting resistant varieties. No single practice solves all rice disease problems.

Rice diseases may be broken down into several groups, including seedling diseases, foliage diseases, sheath and stem diseases, kernel diseases and physiological disorders. The greatest yield losses are attributed to: Brown leaf spot (*Helminthosporium oryzae*); rice blast (*Piricularia oryzae*); stem rot (*Sclerotium oryzae*); brown bordered leaf and sheath spot (*Rhizoctonia oryzae*); and kernel smut (*Neovossia horrida*). Foliar fungicides cleared for use on rice control three of the major diseases. Fungicides are applied to approximately 60 percent of the Texas rice crop,

mostly on a preventive basis. If methods were developed for more accurately predicting disease development, producers could reduce the amount of fungicides used. Diseases caused by *Helminthosporium* sp. on grasses have been reduced through higher applications of phosphorus fertilizers. It is possible that a balanced fertility program will also reduce rice diseases.

Insects

Rice production is localized along the Upper Gulf Coast of Texas, and is the most important agricultural commodity of that area. Rice farmers are a progressive group who use the latest technology, methods and equipment. They quickly adopt any insect control practice which would increase their profits.

Rice producers are faced with relatively few insect problems, as compared to producers of other major crops in Texas. However, practically every acre of rice in Texas is treated with insecticide at least once. Rice insect control, and other production practices, should be precisely controlled and properly planned.

Insect pests may reduce both the yield and the quality of the rice crop. Thus, knowledge of the various insects and methods of control are an essential part of rice production. Knowledge gained from this project will be of value not only in Texas and other rice growing states, but also may be applicable to the many other countries of the world where rice is the most important source of food.

Insect pests of rice feed upon the rice plant in all stages of growth. The rice water weevil (*Lissorhoptrus oryzophilus* Kuschel) and fall armyworm (*Spodoptera frugiperda* [J.E. Smith]) damage rice in the seedling stage. The leafhopper (*Draeculacephala portola* Ball), the rice stalk borer (*Chilo plejadellus* [Zincken]) and the sugarcane borer (*Diatraea saccharalis* [Fabricius]) may attack rice in the tillering stage. The rice stink bug (*Oebalus pugnax* [Fabricius]) and the differential grasshopper (*Melanoplus differentialis* [Thomas]) damage rice in the heading stage.

Economic damage from the different species varies from year to year and from field to field. Yield losses from rice water weevil in experimental plots have ranged from 0 to 756 pounds per acre with an average loss of 340 pounds. Rice stink bugs have been shown to reduce yield, milling yield and grade of rice. Insect pests have the estimated potential of reducing the total rice production in Texas 2 to 3 percent annually. Potential losses to individual farmers may be much greater.

Effective, economical insecticidal control measures have been developed for the most damaging rice insects during the past 10 years; however, certain insects are developing resistance to insecticides. Recommendations for using many insecticides may have to be changed in the near future because of insect resistance and insecticide residues.

Limited information is available on the relative resistance or susceptibility of different rice varieties to the various insect pests. Tests have shown that the losses from both the rice water weevil and rice stink bug may be affected by the variety grown. Procedures and

equipment for screening varieties for resistance to the rice water weevil are now available.

Mosquitoes

The riceland of the Upper Gulf Coast is one of the most important manmade sources of mosquito breeding habitat in this region of the state. Mosquito populations emanating from these irrigated wetlands include species which can be vectors for several diseases of man and his domestic animals (including malaria, VEE and dog heartworm). The blood loss and annoyance associated with riceland mosquito activity can cause economic damage to livestock. Mosquitoes also present a significant nuisance problem for people on farms, in recreational areas and in urban areas adjacent to rice wetlands.

Riceland mosquito control methods are very limited in scope, and are primarily based on the use of chemical insecticides. Application of these chemicals is most often under the direction of organized mosquito control districts, or county or municipal public health departments. In some instances, private contractors are employed to augment existing mosquito control efforts or to provide such services in areas where there are no agencies for mosquito control. The primary aim of these chemical-based mosquito control programs is to protect people in cities and towns from attack by adult female mosquitos moving out of the riceland areas. Control efforts are defensive in approach, temporary in nature and almost entirely based on the rather continuous, broad scale use of chemical insecticides.

The 30-year dependence upon chemical mosquito control has caused harmful accumulations of pesticides in the environment, and the development of chemical tolerance on the part of mosquitoes. For these reasons, an integrated system of control is needed, whereby dependence upon the chemicals is reduced, if not eliminated. The goal of such a system would be to use a blend of nonchemical approaches to suppress mosquitoes to levels which can be tolerated by humans in terms of their economy and their health. Insecticides would then be used only in times of emergency, and then in the manner least harmful to the environment.

Weeds

Weeds are a major concern of Texas rice farmers. Historically, the major method of controlling weeds was with cultural practices such as water management and crop rotations. With the introduction of the phenoxy herbicides, many broadleaf weeds were more effectively controlled. However, the phenoxy herbicides did not control grasses. It was not until the introduction of propanil that many of these grass weeds could be controlled. Despite current technology, it is conservatively estimated that weeds reduce yields by 10 percent annually. This amounts to a loss of 500 pounds per acre on 550,000 acres, which equals an annual loss of \$22 million for Texas rice producers. This estimate is based on yield loss, and does not include discounts because of weed seed or lowered

quality of the rice sold. The most troublesome weeds are sprangletop (*Leptochloa* spp.), dayflower (*Commelina communis*, barnyardgrass (*Echinochloa crus-galli*) and red rice (*Oryza sativa*). Weeds such as dayflower and red rice contaminate commercial rice with weed seed that is very difficult, if not impossible, to remove before or during the milling process.

Although nearly all of the rice acreage is treated with herbicides, some weeds are not adequately controlled. Many producers cannot identify species and, therefore, do not know which herbicide or combination of herbicides to use. Some growers are not aware that the effectiveness of herbicides is dependent on the stage of weed growth and water management practices. If farmers could recognize weed species and their stages of growth, herbicide use could be more effective.

Farmers must know which weeds are prevalent in their fields so appropriate preemergence herbicides can be used. Field records should be kept and surveys made to determine the type and extent of specific weed species.

Red rice has become the major weed problem in rice, with losses estimated at \$5 to 10 million annually. Competition studies have shown yield reductions of up to 64 percent from the infestation of three panicles per square foot. Red rice is difficult and expensive to control, and cannot be selectively controlled with herbicides in commercial rice. Control requires an integrated program using a combination of preventive, cultural and chemical methods in conjunction with crop rotations. Demonstrations should be established to show that red rice can be controlled with proper management.

Interrelationship Between Rice Pests

One of the major problems on rice is "peck" or kernel discoloration. This can be caused by insects, diseases or insect transmitted diseases. The primary insect involved is the rice stink bug. Weeds also cause diseases to be more severe. Weeds serve as alternate hosts for the pathogens, and create ideal environmental conditions for disease development.

SOYBEANS:

Soybean production on the Texas Upper Gulf Coast is relatively new; the acreage increased from about 37,000 in 1970 to 450,000 in 1979. While some producers have row crop experience, many are basically rice farmers growing soybeans.

There is a real need for soybean research and education concerning all phases of production, including pest management. All pest management and production practices must be integrated into a system which produces as much as in the past, with a cost and return that will be profitable to the producer.

Diseases

Soybean diseases reduce yields in Texas by an average of 15 percent each year, and can be severe in the Gulf Coast regions of Texas. Disease development is

dependent on several factors such as varieties, cropping practices, temperature and moisture. At the present time, the most economically damaging soybean diseases in Texas are caused by anthracnose (*Colletotrichum truncatum*), pod and stem blight (*Diaporthe phaseolorum* var. *sojae*) and *Cercospora* sp. which cause purple seed stain and premature defoliation. Approximately 45 to 50 percent of the soybeans in the Gulf Coast are treated with foliar fungicides each year. It is possible that disease incidence could be directly correlated to weather conditions so that fungicide could be applied only when needed. Several states have developed a point system to determine if foliar fungicide applications are necessary. This system has not been evaluated in Texas.

Insects

The three-cornered alfalfa hopper causes damage throughout the soybean growing area. More needs to be known about economic thresholds, population dynamics, detection and control of this pest. Stink bugs which attack soybeans include the southern green stink bug (*Nezara viridula*), the green stink bug (*Acrosternum hilare*) and the brown stink bug (*Euschistus servus*). Although useful economic thresholds have been established for these pests, more information will be needed as the value of the crop and potential yields change.

Foliage feeding insects are a severe problem at times, and as some feed also on the pods, damage may be compounded. The major foliage feeding pests include the soybean looper (*Pseudoplusia includens*), the cabbage looper (*Trichoplusia ni*), the velvetbean caterpillar (*Anticarsia gemmatilis*), the green cloverworm (*Plathypena scabra*), the corn earworm (*Heliothis zea*), the blister beetles (*Epicauta* spp.) and the cucumber beetles (*Diabrotica* spp.).

About 50 percent of the soybean acreage in the state receives one or more applications of insecticide each year. Basic information on detection techniques and economic thresholds would result in a more efficient use of pesticides.

Weeds

More than 30 weed species infest soybean fields in the United States. Since soybeans in the Texas Coastal Prairie are rotated primarily with rice, they are infested not only with the normal soybean weeds, but also with many rice field weeds not associated with soybeans in other parts of the country.

Weeds compete with the crop for light, moisture and nutrients, reducing soybean yield and quality. Weeds harbor insects and diseases which can cause additional losses. It is estimated that weeds cause a 15 percent loss in the Texas soybean crop. This estimate is probably low for the Upper Gulf Coast, where high rainfall and a long growing season contribute to the competitive ability of weeds. However, a 15 percent loss represents a loss of \$14.6 million to Upper Gulf Coast soybean producers.

Although many farmers use herbicides, they do not completely understand the susceptibility of particular

weeds to different herbicides. Specific herbicides only control a limited number of weeds.

Soybean farmers need to use post-directed herbicides more extensively for weeds that are not controlled by soil applied herbicides.

Some weed species, such as redweed (*Melochia corchorifolia*), morningglory (*Ipomoea* spp.), hemp sesbania (*Sesbania exaltata*), dwarf muskmelon (*Cucumis melo*) and red rice (*Oryza sativa*), are becoming widespread because they are difficult to control with available herbicides. Others could be controlled if farmers fully understood proper application techniques. Although most growers use some type of herbicide, in many instances, they are neither using the correct chemical nor using it properly. More educational programs should be provided in the area of weed control.

Interrelationship Between Soybean Pests

Pod abortion is one of the major problems in soybeans. The problem is complex in that both environmental conditions and stink bugs will cause it. Most soybean experts recognize that insects alone cannot cause the magnitude of pod abortion that commonly occurs. It is believed that insects serve as vectors for plant pathogens which also contribute to pod abortion. Weeds compete with soybeans for soil moisture during all stages of growth. They also serve as alternate hosts for both insects and diseases. Heavy weed infestations restrict air movement and cause pockets of high humidity ideal for disease development. It is important that an integrated control program for all soybean pests be implemented.

Proposed Program Strategy

COTTON:

Insects

In the Upper Gulf Coast cotton must be planted and harvested early to escape September rains and late season insects. The cotton variety planted should be cold tolerant, early maturing and produce acceptable yields of high quality lint. Using such a variety, coupled with short season production practices, should increase the probability of crop harvest and stalk destruction before September.

In order to produce an early maturing crop, planting should be completed before mid-April. However, March is usually too early to plant since cotton grows slowly in cold weather, is subject to damage by thrips and aphids and provides food for overwintered weevils. Late April planting may be best for northern parts of the area if very short season (120 days) crops can be grown.

Excessive nitrogen fertilizer causes lush, green growth during late July and August that is very attractive to bollworms/budworms. The minimum amount of nitrogen fertilizer (about 50 pounds per acre) is recommended as needed to produce desired yields without delaying maturity.

Early Season Pest Management

Thrips and cotton fleahoppers are usually the most damaging early season pests. The decision to treat with insecticides for early season pests should be based not only on the number of pests present, but also on the degree of damage. For thrips, it is suggested that the first true leaf bud on seedling cotton be observed carefully for any abnormal curling. If 15 plants per 100 sampled show abnormal leaf curling, and 50 percent of the plants are infested with thrips, control is needed. Research indicates that thrips control is seldom profitable. Cotton fleahopper infestations should be treated if 15 to 25 percent of the pinhead-sized squares are damaged, and 25 to 50 fleahoppers are counted on 100 plants. Treatments should not be initiated for square damage alone, since many other factors may cause small squares to shed. Broad spectrum insecticides should be avoided.

Intensive sampling for overwintered boll weevils should be conducted during a 3- to 5-day period immediately before the first 1/3-grown squares are found in the cotton. If a single adult weevil is found, or if 10 percent of the small squares are damaged, one to three applications of insecticides at 4- to 6-day intervals may be needed. To prevent egg laying it is critical that these treatments begin when the first 1/4-grown squares are available. It is not profitable to treat earlier than this. Applying insecticides several times over a long period increases the risk of a *Heliothis* outbreak. It is preferable to treat only fields or portions of fields that are infested. Area-wide stalk destruction by September 1, plus the conservation of ants, other predators and parasites, may eliminate the need for chemical control of the boll weevil.

Mid-Season Pest Management

Insecticidal control of cotton insects should be avoided, if possible, from first bloom until first hard bolls. Most insecticides effective for boll weevil and bollworm/budworm also drastically reduce beneficial insect and spider populations needed to combat insecticide resistant tobacco budworms. However, selective insecticides are now available that do little harm to beneficial insects. The bacteria *Bacillus thuringiensis* (Dipel® or Thuricide®) and the nuclear polyhedrosis virus (Elcar®) are of value for *Heliothis* control. The effective use of these materials in a pest management program requires the assistance of a knowledgeable consultant.

Late Season Pest Management

Reducing insect pest populations in late summer and fall can greatly simplify production the following year. During this time, boll weevils, bollworms/budworms and pink bollworms build up reserves of fat in anticipation of winter when no food is available. If food sources can be removed before insects build fat reserves, they will starve. Stalk destruction deadlines have long been an effective tool in the management of the pink bollworm. Current stalk destruction deadlines are October 10 in southern portions of the area and October 20 in northern portions. These dates are

too late to be very effective for boll weevil control, and should be moved up about 40 days if possible. However, if stalks cannot be destroyed before September, an insecticide should be added to the defoliant or desiccant, and insecticides applied at 10-day intervals until the stalks are destroyed. Diapause boll weevil control programs must include all producers in an area to be effective.

Weeds

Objectives of the cotton weed control program include:

- 1) To determine by field survey the distribution and degree of infestation of different weed species on cropped and adjacent non-cropped land.
- 2) To train producers in recognizing weed species and planning control programs using crop rotation, tillage and herbicides.
- 3) To publicize accomplishments of the weed management program, and encourage the acceptance of sound weed control practices.

GRAIN SORGHUM:

As with cotton, early harvest and stalk destruction is the most important cultural practice for preventing insect and disease damage in sorghum.

Diseases

If sorghum matures during a rainy season, anthracnose probably will occur. Inoculum survives in debris, on wild sorghum species, or may be seed-borne. Partial control is possible by avoiding crop maturity during wet weather, rotating crops so that inoculum from debris is decomposed, or by eliminating wild hosts such as *Sorghum halepense* or other *Sorghum* spp. Anthracnose resistance is available in several hybrids.

Mosaic diseases appear to be present wherever sorghum is grown. Damage is related to the time of infection, the amount of infection, reaction of the host to the virus and the presence of insect vectors and the Johnsongrass virus reservoir. Control of mosaics depends in part on eradication of susceptible collateral hosts, avoidance of the vector and host resistance. Collateral hosts often are abundant in non-cultivated areas, and therefore difficult to control. Hosts such as Johnsongrass and sugarcane may be cultivated, and tolerate strains of the virus which cause damage to sorghum. Many mosaic resistant sorghum varieties are available.

Grain mold, or weathering, occurs primarily on sorghum seed following maturation. However, infection of seeds begins early in their development, often immediately after flowering. Should there be prolonged periods of humid weather following flowering and during grain maturation, the naturally occurring microflora begin to digest the seeds, resulting in losses in weight and endosperm quality, and germination. Since the disease is only a threat in humid areas, current research involves selecting genotypes which resist molding in the field. Fortunately, superior levels of resistance are being developed.

Sorghum downy mildew spread rapidly throughout the sorghum growing regions of South Texas. While actual losses in most years are not great, the real losses in some years are alarming. Sorghum downy mildew is a soil-borne pathogen with a short-lived asexual phase which at times causes considerable secondary spread. The disease has systemic and local lesion phases. The former almost always results in a barren plant. Both grain yield and forage losses are high. Today, planting resistant varieties appears to be the most promising control method. Many sorghum cultivars have good levels of resistance under field conditions unless high levels of conidia are present in an ideal environment during the first few days following seedling emergence. Few hybrids are known to be absolutely free from infection every year; that is, low levels of disease will occur when high levels of conidia are present in all but a few of the most resistant cultivars known.

Deep tillage is a beneficial cultural practice for controlling downy mildew. Trapping of soil-borne spores also appears promising, as does crop rotation. Prolonged cultivation of downy mildew resistant hybrids greatly reduces the quantity of residual inoculum. For example, in the southern United States, infected maize rarely develops oospores, and planting maize following maize tends to eliminate the disease. In sorghum growing regions where downy mildew is important, an oospore-producing *Sorghum* host must be present for the disease to reach economically significant levels. Losses can be partially avoided by overplanting, since most plants systemically infected as seedlings are poor competitors. Planting date is more critical for maize than for sorghum. For some unknown reason, sorghum infection occurs with a fairly wide range of environmental conditions. High quality, rapidly germinating seeds tend to escape infection more than partially deteriorated seed.

Stalk and root rot problems, like many other diseases, are complex. The most widespread and damaging is charcoal rot, caused by *Macrophomina phaseolina*; it only develops during periods of high temperature when plants are under drought stress. In general, high-yielding, weak-stalked, densely planted hybrids develop charcoal rot most rapidly. Control becomes, at times, a management compromise.

Under irrigation, charcoal rot is not a problem. Dryland sorghum rarely develops charcoal rot if plant densities are low. The severity of the disease is directly related to the rapidity of onset and the severity of the temperature-moisture stress. Hence, plants that are hardened off are less likely to become diseased than those receiving numerous, light rainfalls followed by a long dry period. Early harvesting will prevent losses, but wet grain must be dried artificially before it can be safely stored.

Some hybrids have moderate levels of resistance to the lodging caused by charcoal rot. Many of the bronze hybrids from a Wheatland-type seed parent are less likely to lodge than similar hybrids from other seed parents.

Fusarium stalk rot develops under similar conditions as charcoal rot; the two diseases sometimes occur simultaneously.

Seedling root rot, caused by various fungi species, occasionally causes poor or irregular stands. Planting poor quality seed in soil that is too wet or too dry, too hot or too cold, predisposes sorghum to fungus seedling diseases.

Covered kernel smut and loose kernel smut are controlled with seed treatment fungicides. Head smut has not been controlled chemically; rather, emphasis has been on control through host resistance. Since several new races of head smut have appeared during the past 2 decades, host resistance and pathogen variants must be closely monitored. It is not safe to continuously plant one hybrid in areas with past histories of smut. Varieties should be rotated.

Most of the foliar diseases, other than rust and perhaps *Helminthosporium* leaf blight, can be prevented by crop rotation and destruction of debris. Taller sorghum varieties are less susceptible to many foliar diseases because they primarily invade the lower leaves. Lower plant population, which permits better air movement, also is helpful. Air-borne foliar pathogens are less affected by these practices, so planting resistant varieties is important. Leaf blight inoculum spreads from infected collateral hosts such as other *Sorghum* spp. Eradicating these hosts reduces the probability of serious losses.

Insects

Early Season Pest Management

Grain sorghum should be rotated with other crops to prevent the buildup of Johnsongrass which serves as an early season host of sorghum midge. Soil insects such as wireworms, rootworms and white grubs often cause severe damage, and may require control.

Mid-Season Pest Management

Sorghum should be planted before June 5 so that it will not be in the blooming stage when sorghum midge populations are high. Insecticide should be applied if an average of one midge per head is present when heads begin to flower. Additional applications should be made at 3- to 5-day intervals if midge populations persist while sorghum is blooming.

Late Season Pest Management

The sorghum webworm is often a serious problem in late planted sorghum. Early planting and plowing under crop residues to destroy overwintering larvae are important cultural control practices.

Weeds

Strategies for sorghum weed management are the same as those described for cotton.

RICE:

Diseases

Because rice diseases are difficult to recognize and available fungicides control only certain diseases, rice producers are encouraged to use all available technol-

ogy to reduce disease problems. New varieties have no resistance to the common races of blast. Information on blast, such as initial spore showers and weather related conditions, is being developed by the Harris County IPM Program.

Disease incidence and environmental conditions should be monitored weekly during periods of peak disease occurrence. Cooperating producers should receive the findings in writing, and be counselled by the county pest management specialist and other support personnel.

Insects

Rice plants are injured by the adult rice water weevil feeding on the leaves, and by larvae (root maggots) feeding on the roots. Adult weevils are attracted to fields being flooded, and are most numerous where water is deepest and plant stands thinnest. These areas should be inspected 1 week after flooding by checking the young terminal leaves (leaves that are one-half to one-third unfolded and flattened out) on 100 or more plants. If 50 percent or more plants have one or more feeding scars, the field should be treated. Control measures are usually economically beneficial if larval populations are reduced below 25 per foot of row.

The fall armyworm feeds on rice in the seedling and tillering stages. Larvae feeding on seedling rice before flooding can reduce stands severely. Flooding the field forces the larvae to feed above the water level and reduces the chance of stand loss. If flooding is impractical, insecticides should be applied. Economic thresholds have not been determined for this insect.

The rice stink bug, both the adult and nymphal stages, feeds on rice after heads emerge and causes lower yields and grades. Fields should be scouted *at least weekly* with a 15-inch sweep net, beginning when heads have emerged, and insecticide applied when there are 10 or more stink bugs per 10 sweeps. Repeat applications may be necessary to maintain populations below this level until grain is in the hard dough stage. The rice stink bug is a mobile insect, so infestation can occur quickly, especially from grassy areas adjoining rice fields. Initial infestation usually is greatest around the borders of a rice field, so these areas should be scouted first.

Riceland Mosquitoes

Although much is known about non-chemical methods of mosquito control, there is no intensified, coordinated program for controlling riceland mosquitoes. Such a program is needed. Since riceland mosquitoes are dependent upon the crop environment, they should be vulnerable to any modifications in that environment. For this reason, it is possible that riceland mosquitoes could be controlled by a combination of chemical methods and modified cultural practices.

In order to implement an effective riceland mosquito management program we must:

- 1) Develop nonchemical methods of riceland mosquito control to lessen the present dependence on insecticides.

- 2) Develop methods for using pesticides in a more economical and environmentally compatible manner.
- 3) Conduct efficacy and safety tests to demonstrate the value and environmental impact of new pesticides being proposed for mosquito control, and to determine the effects of pesticides directed toward other pests on mosquito populations.
- 4) Study riceland mosquito population dynamics, interaction of mosquitoes with their environment, dispersion, migration, dormancy, behavior and the biotic factors that affect mosquito survival.
- 5) Develop computerized models for forecasting mosquito outbreaks and for optimizing the effectiveness of control strategies. These models will also be used to assess the compatibility of proposed mosquito management schemes with those proposed for management of the cropping system.
- 6) Demonstrate the cost/benefit ratio of proposed mosquito management programs to the general public.
- 7) Train pest management specialists by involving students and post doctoral fellows in the research and Extension programs to be conducted, and by incorporating the new knowledge arising from this program into the curricula of the university.
- 8) Conduct workshops and demonstrations to illustrate the efficacy of the IPM approach to mosquito management in the riceland agroecosystem.

Weeds

An efficient weed management system must use preventive measures, crop rotation, soil and water management, cultivation, natural enemies and herbicides. Preventive measures can be described as sanitation. Only seed rice that is not contaminated with weed seed should be planted. And all equipment moving from or through an infested field to a clean field should be cleaned. If a few weeds appear they should be pulled before they set seed and further contaminate the field.

Crop rotation is the only effective method of controlling red rice. A field can be rotated to soybeans or sorghum and the red rice controlled in the alternate crop. Usually it takes 2 years of an alternate crop to control a moderate infestation. If the infestation is severe, two complete 3-year cycles are necessary.

Soil and water management influences weeds and their control. A good seedbed allows the weed seed to germinate uniformly, making both postemergence and preemergence herbicides more effective. Water management has been used for weed control since before herbicides were developed. Many weeds, such as barnyardgrass and red rice, do not germinate in extremely wet soil. However, under early season flood conditions aquatic weeds become more prevalent.

Mechanical cultivation during the growing season is not practical. However, cultivation after rice harvest can destroy weeds before they produce seed. Cultivation in alternate crops or on fallow fields is often necessary for weed control.

Using insects to control alligatorweed (*Alternanthera philoxeroides*) in irrigation canals shows prom-

ise. In most instances, several weed species grow together and need to be controlled. Biological control is most effective when a single weed species is of concern.

Since the introduction of the phenoxy herbicides, particularly propanil, herbicides have become the backbone of almost all rice weed control programs. Postemergence herbicides, coupled with proper water management, have contributed significantly to increased rice yields. As residual herbicides are developed, the rice producer will be able to manage his water for maximum rice production instead of for weed control.

SOYBEANS:

Diseases and Insects

Development of new soybean varieties has reduced diseases such as pod and stem rot, but the new varieties have no resistance to other common diseases. Information on soybean diseases and weather related conditions is currently being developed by the Harris County IPM Program.

As with rice, soybean diseases, insects and environmental conditions should be monitored weekly during periods of peak disease occurrence. Cooperating producers should receive the findings in writing, and be counselled by the county pest management specialist and other support personnel.

Weeds

Efficient weed management depends on using the same measures as described for rice weed control — preventive measures, crop rotation, soil management, cultivation, natural enemies and herbicides.

In the Upper Gulf Coast, crop rotation with proper weed control in the alternate crop is effective for several species. Rotating a Johnsongrass (*Sorghum halepense*) infested soybean field to rice will help because the flooding controls Johnsongrass. This rotation also helps with morningglory and cocklebur (*Xanthium pensylvanicum*).

Good seedbed preparation helps incorporated pre-emergence herbicides work, and results in a good bed and middle for application of postemergence herbicides.

Mechanical cultivation controls most weeds in the middles. However, in the high rainfall area of the Upper Gulf Coast, cultivation at the proper time may not be possible. Preemergence or preplant incorporated herbicides are insurance against complete weed control failure. Preplant cultivation often destroys several crops of weeds before soybeans are planted. However, this cultivation may deplete soil moisture needed for the crop if timely rains do not occur. Cultivation in the crop, coupled with directed spraying of postemergence herbicides in the row, is an example of integrated weed control that has been an accepted practice in many areas.

Many weeds have natural enemies in the form of insects and pathogens. Insects may feed on hemp sesbania foliage and morningglory seed, but usually only

in small areas. Releasing insects may help with these weeds, but herbicides must be used for other weeds present. Biological weed control is most successful in situations of long term management, such as control of some perennial weeds on rangeland.

Although all soybean producers use cultural weed control methods, herbicides are the most important component of successful weed control programs.

The Texas Rice and Soybean Pest Management Program initiated in Harris County uses technical input from all disciplines related to rice and soybean production. The Texas Agricultural Extension Service, through the county Extension agent, area entomologist, Extension agent-entomology (PM) and other specialists, disperses information on pest management strategies developed by the Texas Agricultural Experiment Station and the United States Department of Agriculture - Agricultural Research Service. These agencies provide information concerning entomological, pathological and agronomic concepts that are used in the pest management pilot program.

The Texas Agricultural Extension Service provides area-wide educational programs for rice and soybean producers.

Data generated by the Pest Management Program is stored in a computer and used to provide economic analyses of the program. Private consultants employed as pest management specialists are providing field data on pest occurrence and distribution, damage, and pesticide use and effectiveness.

GENERAL RECOMMENDATIONS

Because of the complexities of recognizing all pest and beneficial insects; recognizing diseases; knowing the best pest management strategies to use; knowing all the ramifications of pesticide use, such as selection of materials, dosages and application equipment; and understanding Federal and state laws regulating the recommendations, shipment, tolerances, and uses of pesticides, we recommend that all producers obtain the services of qualified, professional entomologists and other specialists to assist in making management decisions. Initiation of pest management techniques, chemical or otherwise, should be based on sound economic thresholds and the best sampling techniques available.

Program Organization and Extension Needs

Integrated pest management demonstrations should be established to study multi-adversity resistant varieties, planting seed quality, crop rotations, flatbreaking and fertilization involving NPK, Na and minor elements.

The South Texas Cotton and Grain Association, Inc. (STCGA) is strong in many of the Upper Gulf Coast counties. Any program proposed by Texas A&M will be supported by this organization. Many producers, both members of STCGA and non-members, actively seek information from mass media

and Extension programs. The importance of modifying cultural practices and the need for field scouting should be conveyed through mass media channels and existing Extension programs.

The pest management programs in Harris, Jackson, Wharton, Fort Bend and Matagorda counties (cotton, sorghum, rice and soybeans) also have played an important role in making producers aware of the benefits of integrated pest management.

The role of the county Extension agents-entomology and plant pathology (PM) will be to:

- 1) Provide technical support for scouting activities.
- 2) Conduct annual scout training schools.
- 3) Help scout supervisors and consultants with field report analysis and decision making.
- 4) Coordinate multi-county involvement in intensive community pest management education programs.
- 5) Expand field demonstrations to gain fuller exposure for pest management programs.
- 6) Assist with general disease, entomological and weed problems.
- 7) Assist with pesticide applicator training and safety programs.

Extension specialists (entomologists, plant pathologists, weed scientists and others) will have the following duties in their fields:

- 1) To provide training for producers, pesticide dealers, field scouts, private consultants, Extension agents (PM), county Extension agents, and area and state specialists.
- 2) To assume responsibility for monitoring pest infestation levels, identifying species and determining the need for cultural and chemical control on program farms.
- 3) To collect and interpret survey data on a) past and present crops, b) past and present pesticide use, c) adjacent pest sources, d) tillage practices, e) pest species escaping control measures and f) post harvest pest control in cropland and non-cropland.
- 4) To develop maps, publications, slide sets, newsletters and other educational aids as necessary to promote integrated pest management among producers.
- 5) To conduct demonstrations on pesticide usage.
- 6) To collect and store computer data to be used in economic evaluations of program impact and in preparation of annual reports.

An Extension weed specialist-pest management is needed to support the above objectives.

There are mosquito control districts in six of the counties most severely affected by riceland mosquito populations. They are Orange, Jefferson, Chambers, Harris, Galveston and Brazoria counties. Extension mosquito management programs are, and should continue to be, coordinated with these mosquito control districts and with city/county health departments in counties without mosquito control districts.

Extension should be more involved in training mosquito control personnel and informing the public about mosquito management. A new state entomologist position should be created to fill this need. The

entomologist would have responsibility for mosquito management activities, including:

- 1) Providing technical information to mosquito control districts and city/county health departments.
- 2) Coordinating Extension activities in the area of public health entomology with those of the State Health Department, and with Extension specialists involved with crop pest management in riceland and other agricultural wetlands.
- 3) Conducting workshops on mosquito management and control technology in cooperation with the State Health Department and the Texas Mosquito Control Association.
- 4) Creating an awareness of mosquito management needs and methodologies among county Extension agents-entomology (PM) centered in the rice growing areas of Texas.
- 5) Developing educational programs to stimulate public cooperation and support for these activities.

Research Needs

COTTON:

Varieties with higher levels of resistance to cold, nematodes and *Phymatotrichum* root rot are needed. This is being accomplished in the multi-adversity resistance research program. More information is needed on effectively using sodium and ammonia to reduce survival and production of *Phymatotrichum sclerotia*. We also need research on reducing nematode populations in sandy soils and the effectiveness of okra leaves and frego bract in reducing boll rot damage. Research should evaluate each control practice individually and in combination with others to ascertain the most effective and practical strategies. The Texas Agricultural Experiment Station does not presently have the manpower necessary to carry out such research, and should add personnel as funds become available.

Producers desperately need improved sampling techniques for overwintered boll weevils. Currently the trend is toward "pre-emptive" spraying, or automatic chemical control of overwintered boll weevils if the field has a history of boll weevil damage. Since most fields in the Upper Gulf Coast have a history of some weevil damage, many are sprayed unnecessarily. Of course, if boll weevils are present in damaging numbers and are not controlled, economic losses may be suffered. Thus, what producers need is a sampling technique which will help them make the correct decision 80 to 90 percent of the time.

Research should continue on the new SP and CAMD multi-adversity resistant cottons which are earlier and have partial resistance to fleahoppers. Other new materials available for pilot tests include ORSLE and ORMAR-S which are okra leaf, frego bract and smooth types, and LEBO-2 and CDPS which are conventional.

The impact of certain selective insecticides, and selective methods of insecticide application, on pest and beneficial insects in the cotton-sorghum-soybean-rice ecosystem should be investigated.

Sampling methods for all arthropod pests and beneficials should be evaluated. Research on biological control agents should continue.

The sorghum pest situation in the Upper Gulf Coast is quite similar to that in the Lower Gulf Coast area, except for the influences of higher rainfall in the Upper Gulf Coast area. The research proposed for the Lower Gulf Coast would be applicable to the Upper Coast area.

Texas Agricultural Experiment Station weed scientists at College Station will assess the suitability of new herbicides. Limited tillage research conducted by AR-SEA-USDA agricultural engineers at Temple may benefit pest management programs. Other weed research needs are:

- 1) Competitive effects of weed species on crop yields.
- 2) Weed and weed seed biology.
- 3) Herbicide residues in cropping systems.
- 4) Herbicide screening on specific weeds.

SORGHUM:

Research on sorghum diseases should include:

- 1) Host resistance for controlling major sorghum diseases.
- 2) Host resistance to minor or secondary diseases such as bacterial stripe, bacterial streak and *Cercospora* leaf spot.
- 3) The influence of Johnsongrass on grain sorghum pathogens, especially a comparison of host debris and Johnsongrass as sources of inoculum.
- 4) Survival of sorghum pathogens within existing cropping rotations (cotton, grain sorghum) and possible new rotations (cotton, maize, sorghum and soybeans), particularly the survival of oospores of *Peyronosclerospora sorghi* and teliospores of *Sphacelotheca reiliana*.
- 5) Biological control of sorghum pathogens.
- 6) Economic thresholds for several of the major and most of the minor sorghum diseases.

Research on sorghum insects should include:

- 1) Pesticide effectiveness and optimum dosages.
- 2) Improved pesticide application (also fertilizer application).
- 3) Effects of pesticides used for grain sorghum on other crops.
- 4) Development of insect resistant and herbicide tolerant sorghum varieties.

Weed research needs include:

- 1) Competitive effects of weed species on crop yields.
- 2) Weed and weed seed technology.
- 3) Herbicide residues in cropping systems.

RICE:

Rice disease research needs are:

- 1) The epidemiology of rice blast.
- 2) The relationship of diseases and insects on "pecky" rice.

In the area of rice insects, researchers should:

- 1) Incorporate host plant resistance into commercial rice varieties.

- 2) Refine action levels for rice stink bug and rice water weevil.
- 3) Establish an action level for fall armyworm on rice.
- 4) Evaluate experimental insecticides.
- 5) Obtain additional data on yield loss from the rice stink bug by using the feeding sheath as an indicator of feeding activity.
- 6) Study the biology, ecology and physiology of rice insect pests and their parasites and predators.
- 7) Screen and test selective insecticides.

Riceland mosquito research is needed in the following areas:

- 1) The effects of the riceland environment on the population dynamics of mosquitoes.
- 2) The current and potential impact of riceland mosquitoes on both rural and urban economies.
- 3) The effectiveness and environmental impact of mosquito management techniques.
- 4) The feasibility of integrating various biological, cultural and chemical control measures into continuous mosquito management programs.
- 5) Analysis of the costs/benefits of riceland mosquito management systems.
- 6) Demonstrating new control methods to the local agencies responsible for their implementation, as well as to the farmers whose land is involved; and using computer networks for forecasting pest outbreaks.

The Texas Agricultural Experiment Station will be aided in accomplishing these objectives through its involvement in a Regional Cooperative Research Project on the Biology, Ecology and Management of Riceland Mosquitoes in the Southern Region (S-122). This project includes the cooperative scientific efforts of experiment station personnel in Texas, Arkansas, Louisiana and Mississippi, and research scientists associated with the USDA-SEA/AR Gulf Coast Mosquito Research Laboratory (Lake Charles, LA) and Insects Affecting Man Laboratory (Gainesville, FL).

Rice weed research should include:

- 1) Evaluation of herbicides, and the relationships between herbicides (particularly the new preemergence herbicides) and water management.
- 2) Weed biology, including seed germination and plant growth.
- 3) Effects of specific weeds on rice yield and quality, and economic thresholds for weeds.
- 4) Relationships between weed incidence and cropping systems, and the effectiveness of weed control in alternate crops.
- 5) Effects of herbicide residues from preceding crops on rice yield.
- 6) Effects of fertilizer timing on weed populations.
- 7) Effects of various water management systems on weed populations.

SOYBEANS:

Research needs in the area of soybean disease include:

- 1) The epidemiology of pod and stem rot.
- 2) The relationships of diseases and insects to soybean quality.

High priority soybean insect research needs are:

- 1) Relationship of diseases and insects to pod abortion.
- 2) Phenology of soybean plant/three-cornered alfalfa hopper.
- 3) Insecticide resistance of cabbage/soybean loopers.
- 4) Economic thresholds for foliage feeders.
- 5) Role of predators, parasites and pathogens in controlling insect pests.
- 6) Soybean computer modeling.

Soybean weed research needs are:

- 1) Evaluation of herbicides and recommendations for controlling specific weed species.
- 2) Weed biology, including seed germination and plant growth.
- 3) Effect of specific weeds on soybean yield and quality, and economic thresholds for weeds.
- 4) Relationships between weed incidence and cropping systems, and the effectiveness of weed control in alternate crops.
- 5) Effects of herbicide residues from preceding crops on soybean yield.

Program Evaluation

The effects of pest management actions on the environment and on long-term profits to producers will be evaluated.

Field monitoring records of participating and non-participating farms will be compared as to 1) the number of weeds at harvest, 2) species of weeds controlled and not controlled, 3) the cost of weed control practices and 4) crop yield.

Various cropping systems and cultural practices will be compared to answer such questions as: Does early planting of sorghum alleviate sorghum midge problems? and Does narrow row planting encourage weeds?

Growers' opinions of the program will be surveyed after the first year. Others who will be asked to evalu-

ate the program include commodity organizations, private consultants, Extension specialists and research personnel.

In the final analysis the success of the program will depend on producer acceptance. Producers will accept practical pest control methods that will increase their profits. Then, integrated pest management will be a success.

Regulatory Needs

No specific regulations are needed for disease control in the Upper Gulf Coast. However, it should be an unwritten rule that only varieties having high resistances to bacterial blight and the *Fusarium* wilt/nematode complex will be planted. A number of such varieties which do well in the area are available. This should be emphasized in each educational meeting.

Pest control districts should be established through producer referendums in various sections of the Upper Gulf Coast cotton growing area. Officers of the districts could establish optimal planting time, plow-up time, cotton varieties, pest control strategies, etc. with the advice of federal and state experts.

The existing pink bollworm regulatory requirements are inappropriate for satisfactory boll weevil management; therefore, it is recommended that *all* stalks be destroyed by September 15. A plow-up date of September 30 should be mandatory, and enforced via regulation.

Regulations concerning mosquito management should be the responsibility of mosquito control districts and the State Health Department.

Certification standards for rice seed might be tightened, especially in regard to red rice seed. Currently, two red rice seed per 10 pounds of rice seed are allowed. Eliminating red rice seed entirely would be costly, but it is the only way to ensure uncontaminated rice seed.

LOWER GULF COAST AND WINTER GARDEN PEST MANAGEMENT PLAN

The Lower Gulf Coast is part of a farming district known as the South Texas Coastal Plains. It extends along the Gulf Coast about 100 miles from Port Lavaca on the north to just north of Raymondville on the south. Within these boundaries, in addition to county Extension offices, are the Texas A&M University Agricultural Research Station at Beeville, the Texas A&M University Plant Disease Research Station at Yoakum and the Texas A&M University Research and Extension Center at Corpus Christi.

The Lower Gulf Coast is farmed dryland, with corn, sorghum and cotton constituting most of the row crop production. Sorghum, the major crop, averages 1 million acres per year. Cotton acreages fluctuate, but normally have little influence on the number of sorghum acres in most counties. The most dramatic increase in the past 5 years has been in corn, from 60,000 acres planted in 1975 to a high of almost 200,000. The most dramatic increases have been recorded in counties where little cotton is grown. Therefore, increasing corn acreage has had a direct impact on sorghum acreage. Other crops grown in the region are rice, peanuts and small grains, primarily wheat.

Four factors led to increased corn acreage. First, corn had a potentially more favorable profit margin than sorghum. Second, grassy weeds are easier to control in corn. Third, corn is less sensitive to iron deficiency, which is common to the Lower Gulf Coast area. Fourth, rainfall has been above average the past few years in most of the northwestern counties.

Since 1977 cotton production in this area has occupied more than 200,000 acres annually. The six primary cotton producing counties are Bee, Jim Wells, Kleberg, Nueces, Refugio and San Patricio. Producers who rotate between cotton and sorghum benefit from easier disease, insect and weed control. The natural regulation of the *Heliothis* complex in cotton is aided by the natural enemies of the pest complex that live in sorghum; as sorghum matures, these beneficial insects move into cotton. This relationship is dependent upon avoiding damaging sorghum midge populations. If there is no need to treat sorghum midge with insecticide, the natural enemy reservoir builds up in sorghum, and no beneficials in cotton are destroyed by insecticide drift from treated sorghum fields. In order to escape midge damage, producers over an entire area must plant early and uniformly.

The major annual cotton pest is the boll weevil. In some years, the cotton fleahopper is a damaging early season pest. Bollworms and tobacco budworms may become pests, especially where insecticidal control is used for boll weevils at or after bloom initiation, or where insecticides drift to cotton from nearby sorghum. Crop losses and cost of insect control amount to between \$2.0 and 3.2 million annually. In areas where the boll weevil is a serious threat, producers generally apply an insecticide to reduce the overwintered population, thereby preventing a damaging first generation in the spring. If the cotton then fruits early, insecticide may not be required for late weevil populations.

The Cotton Pest Management Program in Nueces, Kleberg and San Patricio counties has operated since 1976, covering an average of 10,000 acres. Insect population monitoring, scouting reports and trapping procedures have made it possible to reduce pesticide use in many areas. Producers have learned of the need for early season control of overwintered boll weevils, and have become better acquainted with economic thresholds, insecticide selections, timing and application rates.

Crop rotation is extremely important to pest management. For example, if only sorghum is planted, fields may become progressively more infested with Johnsongrass. Johnsongrass also is an important host of the sorghum midge and diseases that affect sorghum. Where cotton is grown year after year, cotton root rot may become increasingly severe in certain areas.

Sorghum grown without rotation may develop severe iron deficiency that delays blooming to the extent that the sorghum midge will prevent grain from forming unless insecticides are used.

Therefore, cotton and sorghum should be grown in rotation, and rotation is an important tool in integrated pest management.

The sorghum midge is the key insect pest of sorghum in the Lower Gulf Coast. Approximately 10 percent of the sorghum grown receives at least three treatments for this insect. Early, uniform planting dates for sorghum are recommended for preventing midge attacks.

Tropically adapted hybrids recently developed and released by TAES sorghum breeders have a higher yield potential under South Texas conditions than the

standard hybrids. The new hybrids, however, tend to bloom later; therefore, their susceptibility to the sorghum midge must be investigated. TAES and TAEX personnel are determining the role these sorghums may have in the Lower Gulf Coast area.

TAES breeders have found midge resistant material in the world sorghum collection. This genetic material is now being incorporated into agronomically acceptable hybrids. Demonstration plots will be established to further evaluate yield potential and acceptability of these hybrids on the farm.

Other pests of occasional importance are stink bugs, corn earworm, sorghum webworm and certain soil insects. The yellow sugarcane aphid is a problem in some years. Damage from the greenbug is increasing in severity.

Sorghum hybrids resistant to the major diseases are available, but new hybrids must be developed should new races of the disease organisms occur.

Most corn is grown in counties with correspondingly low cotton acreage. Since corn is normally less susceptible to iron deficiency, it has been substituted for sorghum in many fields, and planted on the same ground without rotation. As a result, the western corn rootworm could become a serious pest. This insect has already been reported in Bee, DeWitt, Karnes, Goliad and Victoria counties. Crop rotation is viewed as the most effective way to deal with this pest. Other corn insect pests include wireworms, seed corn maggots, white grubs, cutworms, corn earworms and fall armyworms. Approximately 75 percent of the corn is given a rowband insecticide application at planting. The value of this practice must be further evaluated.

Proposed Program Strategy

Current and future pest management technology should be made available to producers for the cotton-corn-sorghum agroecosystems of the Lower Gulf Coast area. The crops should be considered as interacting biological units where pest control strategies on one crop affect another.

We recommend that cotton producers obtain the services of qualified pest management consultants to assist in making control decisions.

There are several private consultants and two Extension agents-entomology (PM) in the six Lower Gulf Coast counties. Each Extension agent-entomology (PM) is responsible for three cotton producing counties. Communication of pest management technology to sorghum and corn farmers should be the responsibility of the area Extension entomologist, area Extension weed specialist, Extension agent-entomology (PM), county Extension agents, private consultants and leading producers through formal educational programs and field demonstrations.

CORN:

Disease monitoring and selection of superior hybrids should be encouraged through demonstrations and research plots. Demonstrations showing

producers how to manage the western corn rootworm through crop rotation should be intensified. In addition, the efficacy of at-planting, band application of insecticides for certain soil pests should be investigated. Corn pests that should be monitored include seed corn maggots, white grubs, cutworms, corn earworms and fall armyworms.

COTTON:

Variety selection is the foundation of the Cotton Pest Management Program. In recent years, Lower Gulf Coast farmers have switched to the short season cotton varieties that can be either stripper harvested or gathered with spindle pickers. Production practices that foster early harvest, such as reduced nitrogen levels and narrow row planting patterns, should be encouraged if they can be adapted to farming conditions in the area. The goal should be to harvest cotton 120 to 130 days after planting.

Planting dates should be between February 15 and April 1, depending on soil temperature and moisture conditions. To produce a cotton crop that is early enough to escape the increasing possibility of rainfall in late August and early September, and the associated insect problems, it is necessary to obtain a good stand at first planting. Therefore, only high quality, fungicide treated seed should be used.

The practice of treating cotton for overwintered boll weevils must be carefully studied. There are certain disadvantages connected with the practice, but, where needed, the advantages outweigh the disadvantages. Two factors must be considered: 1) Fields that are far from overwintering sites, where population build-up in past years has not occurred until the second weevil generation (after about a month of blooming), should not be treated; and 2) Applications must be made at exactly the right stage of square development. If boll weevils are found in cotton, insecticide should be applied just before the first 1/3-grown (1/4-inch diameter) square stage. If the first application is made too many days before this size square is present it will not be as effective because research shows that boll weevils do not colonize in large numbers until 1/3-grown squares are present. A second application should be made 4 to 5 days after the first. The insecticide must be applied before there is a risk of increased bollworm activity to preserve beneficial arthropods that keep bollworm populations under biological control. Beneficial arthropods should be given every chance to build up after these treatments to minimize the need for further insecticide applications for bollworm control.

Producers should be encouraged to avoid mid- and late season insecticide use, if possible. They should rely on field scouting and economic thresholds to determine the need for treatment.

Bolls are increasingly likely to escape weevil damage as they age. The advantages of earliness are negated, however, if weevil infestation is heavy early in the season. Square damage will reduce the number of blooms and bolls set, and bolls that are set will likely be damaged. For the system to work, overwintered

and first generation weevils must not occur in large populations. A delay of only a few days in the second generation weevil build-up will allow large numbers of bolls to mature beyond the point of excessive damage. Therefore, economic thresholds can be greatly increased for the second and later generations based on the number of older bolls present. If adequate boll set has occurred by day 35 of blooming, then 50 percent punctured squares could be tolerated. In another week, nearly 100 percent punctured squares could be tolerated without significantly affecting yield.

The Cotton Pest Management Program is centered around rapid harvest and early stalk destruction. In South Texas, early, complete stalk destruction has been shown to be a much better way to reduce diapausing overwintered boll weevils than the use of chemicals. The reason is simple. If boll weevils can't find food, they can't survive. Once harvest is complete, stalk destruction must be immediate and thorough. Otherwise, rains could prevent field work for some time.

Current cotton pest management procedures are outlined in TAEX publications B-1200, *Keys to Profitable Cotton Production in the Coastal Bend*, and B-1204, *Management of Cotton Insects in South and East Texas Counties*.

SORGHUM:

Current sorghum insect and disease management strategies are outlined in TAEX publications MP-1310, *Keys to Profitable Grain Sorghum Production in the Coast Prairies and Coastal Bend*; B-1220, *Insect and Mite Pests of Grain Sorghum — Management Approaches*; L-842, *The Sorghum Midge and Its Control*; MP-1352, *Disease Ratings of Commercial Sorghum and Corn Hybrids*; L-723, *Identifying and Correcting Iron Deficiency in Field Crops*; and MP-1059, *1981 Suggestions for Weed Control with Chemicals in Corn and Grain Sorghum*.

Producers need more demonstrations on methods of correcting iron chlorosis, as this can be a serious problem.

Sorghum should be planted between February 15 and March 15 in the southern Lower Gulf Coast counties, but planting could be extended to March 25 in the northern counties. Early flowering hybrids should be used if sorghum is planted near the later dates suggested. If blooming is complete by May 25 in the south or June 5 in the north, significant sorghum midge damage usually will not occur. Producers should strive for uniform planting within an area so that blooming will occur over a short period.

Program Organization and Extension Needs

Interdisciplinary result demonstrations and other educational programs should be conducted through the cooperative efforts of Extension specialists, TAES researchers, county Extension agents, county program

building committees and industry. Extension should increase its involvement in the following:

- 1) Recruiting and training part-time field technicians, funded by growers, in areas where scouting programs operate.
- 2) Training field scouts.
- 3) Adding one full-time assistant to Extension specialists and agents, to help in maintaining equipment, establishing crop demonstrations, gathering field data and summarizing demonstration results for use in county result demonstration handbooks.
- 4) Providing farmers with educational materials and programs on disease, insect and weed management.
- 5) Establishing more pest management demonstrations.
- 6) Promoting adoption by farmers of improved pest management technology.

The present pest management program will gradually increase in size as qualified scouts and scout supervisors are found. There will be a need for professional crop consultants to replace county programs where possible. The Extension agent-entomology (PM) will help TPMA producers train field scouts, and will encourage the use of professional consultants and independent field scouts. Plans are underway at present to train competent crop consultants. Annual training sessions will be conducted for producers, scouts, consultants and other interested persons.

It is also important for Extension to provide producers, scout supervisors and consultants with pest population estimates, and, when necessary, to help with analysis of field reports. More emphasis will be directed toward community and county-wide involvement in pest management practices. Producers must become aware of all of the factors involved in making pest control decisions.

The Extension agent-entomology (PM) will need to work closely with the county Extension agent in demonstration work, pesticide applicator training, safety programs and general entomological problems.

The implementation of pest management strategies can best be effected by knowledgeable growers who establish pest management districts to provide the political structure for unified pest management plans. Planting dates, stalk destruction dates and large scale insect control programs can best be handled within the framework of a pest management district.

Research Needs

Researchers from several disciplines must join forces to solve the pest problems facing cotton, sorghum and corn producers. Unilateral efforts by single disciplines often are fragmented and incomplete.

CORN:

To manage corn diseases, insects and weeds, research must be conducted on several fronts:

- 1) Disease resistant hybrids must be developed continually to overcome new races of disease causing organisms as they occur.

- 2) More understanding of the relationship of insects to disease transmission and severity is needed.
- 3) More effective and efficient ways of using herbicides in corn should be developed.
- 4) Research on optimum plant populations and fertilizer requirements, including trace elements, must be conducted.
- 5) A study should be made of yield reductions caused by white grubs, corn earworms and fall armyworms.
- 6) Research is needed on the role of the southern and western corn rootworms, so that economic thresholds can be developed.
- 7) More efficient management strategies for soil insect pests should be investigated.
- 8) The efficacy of at-planting soil insecticide applications should be evaluated.
- 9) Several areas of weed science research are needed for the south Texas area. They are: 1) developing technology for sampling weed and weed seed populations in order to determine appropriate herbicide(s); 2) studying the population dynamics, movement and distributional pattern of weed populations; 3) investigating the potential use of economic thresholds in controlling major weed species; 4) studying the biology of major weed species; 5) studying the movement, persistence and absorption of herbicides in semi-arid soils; 6) determining the behavior of herbicides on specific perennials (penetration and trans-location studies); and 7) correlating herbicide residues to arid soils on rotational crops.

COTTON:

Over the last 5 years, considerable research information on cotton insect management has accumulated. This information should be developed into pest management strategies, as there is an urgent need to provide new data for farm pest management programs. We suggest that a joint program, consisting of research and Extension personnel, be developed to demonstrate the value of these new pest management strategies in a county-wide, short season cotton pest management program. The following information should be gathered:

- 1) The influence of planting dates on fleahopper, bollworm and boll weevil damage, and the cost of control.
- 2) The impact of the new short season cottons on insect and disease control.
- 3) The ideal timing of applications for overwintered boll weevil, the number needed and the cut-off date for applications.
- 4) The impact of fleahopper control on subsequent populations of bollworms, and the level of bollworm damage sustained.
- 5) Best strategies for managing mid- and late season secondary bollworm outbreaks.
- 6) The effect of a long term, area-wide, short season system on boll weevil numbers.
- 7) The best measures to take when cotton remains in the field until late season. For example, would fall

diapause and/or mandatory shredding and plow-up be most effective?

In addition to the above program, the following areas of research need to be expanded.

- 1) Breeding and evaluation of pest resistant cotton varieties.
- 2) Use of pheromone traps to detect and measure early season boll weevil activity, thereby establishing an economic threshold for determining the need for early season treatment.
- 3) Best crop rotation system, variety and planting date to maximize the benefits of beneficial arthropods. First, of course, we must learn the species and importance of the beneficial insects present in cotton and sorghum.
- 4) Host plant resistance characteristics, such as glabrous, high tannin, frego, nectarless and okra leaf, for reducing fleahopper, bollworm and budworm damage.
- 5) Importance of alternate hosts on boll weevil survival and subsequent population development.
- 6) Improved economic injury levels for cotton insect pests based on new, short season, insect resistant varieties.
- 7) Adjustment of economic injury levels with the changing phenology of the cotton plant and its changing susceptibility to damage.
- 8) Best selective and/or broad spectrum chemicals for a short season pest management program.
- 9) Use of trap crops for boll weevils.
- 10) Impact of row spacing and plant density on insect pests.
- 11) Impact of plant growth hormones on cotton insect pests and beneficials.
- 12) Impact of recommended insecticides and herbicides on cotton plant growth, fruiting and fiber properties.
- 13) Importance and potential usefulness of various biological control agents such as bacteria, viruses, and released parasites.
- 14) Cost/benefit ratios for the most practical insect control strategies developed from the above.
- 15) Development of new pest management programs based on the information and economics determined above.
- 16) Relationships between plant nutrition and pests.
- 17) Weed research as described in item 9 under corn.

Expansion of these research objectives over the next 5 years would lead to a more profitable and biologically sound pest management program than we have today.

SORGHUM:

Sorghum, the major crop in the Lower Gulf Coast area, is the crop most intimately related to cotton both agronomically and entomologically. The relationship of cotton and sorghum must be a primary consideration in the establishment of area-wide pest management systems. However, sorghum insect research in this unique geographical area has essentially been lacking. There is an urgent need for a sorghum research entomologist to formulate pest management strategies applicable to this semi-tropical area.

The southward spread of the greenbug in Texas threatens sorghum production in an area where, until recently, the pest was of little concern. Sound pest management strategies for dealing with this pest are needed in order to circumvent the insecticide resistance problem encountered in the High Plains area. Greenbug resistant sorghum hybrids could become very important.

Sound biological and ecological studies of the sorghum midge are needed. Damaging midge infestations on early planted grain sorghum have occurred in recent years, indicating an apparent change in the pest's population dynamics. Recent discoveries of sorghum midge resistant sorghums could influence management systems, but considerable testing and evaluation under local conditions will be necessary. Research is needed on integrating resistant sorghums with other control tactics so that sorghum can be planted late when adverse conditions prevent early planting.

Research needs described above also apply to the sorghum webworm. Cultural practices such as date of planting should be investigated, and research results applied to the pest management scheme for the area.

Producers and entomologists are concerned over the increased incidence and severity of the yellow sugarcane aphid and the sugarcane rootstock weevil. These insects are still only occasional pests, but they must be considered in establishing pest management programs.

The close association of most sorghum pests with Johnsongrass needs to be investigated, since Johnsongrass inevitably increases in areas of intensive sorghum production.

Insecticides will remain an integral part of the pest management scheme, although research will be needed in order to prevent disruption of the agroecosystem. Insecticide treatments in sorghum could eliminate beneficial species in that crop and also affect adjacent cotton. The relationship of beneficial cotton and sorghum insects should be studied.

Program Evaluation

The success of the program will be determined by the degree of its adoption by Lower Gulf Coast producers, and by the effect of these technologies on production and net profits. Modifications should be made as improvements are developed either at the farm level or from research.

Regulatory Needs

Pink bollworm regulations state that cotton should be planted between February 15 and April 20 in the Lower Gulf Coast area, and that all stalks should be destroyed by September 28.

These regulations are inappropriate for satisfactory boll weevil management; therefore, it is recommended that cotton be planted between February 25 and April

1, and that all stalks be destroyed by August 31. These dates should be enforced.

WINTER GARDEN

A number of crops are grown in this region southwest of San Antonio, including vegetables, peanuts, cotton, corn and sorghum. Agricultural production in this area uses high rates of fertilizer, insecticide and irrigation water.

Insect, disease and weed problems in this area are quite similar to those of the Lower Gulf Coast. There are some differences, however. Cotton is grown under full irrigation and the insects nurtured by this approach require much more chemical control. Cotton is often treated 10 to 14 times.

Cotton is harvested mostly by spindle pickers, unlike the Lower Gulf Coast where cotton is stripper harvested. Spindle harvest takes longer, so there is a larger food source for overwintering boll weevils. In some years, pink bollworms survive in surprising numbers.

Cotton acreages in the Winter Garden vary seasonally, from 3,000 acres to as much as 50,000. Sorghum production is more constant, about 300,000 acres each year. About 50,000 acres of peanuts and 80,000 acres of corn are planted each year in the Winter Garden.

Corn suffers from the same lack of rotation found in the Lower Gulf Coast. The western corn rootworm is a serious pest. In addition, insecticides used on corn can trigger outbreaks of the Banks grass mite, which is resistant to acaricides. As in the Lower Gulf Coast, insecticides applied to either corn or sorghum may drift to adjacent cotton, resulting in the destruction of beneficial arthropods that keep bollworm and tobacco budworm populations under biological control.

Peanuts have an insect pest unique to the Winter Garden. This is the burrowing bug, which can greatly reduce the quality of harvested peanuts. Burrowing bug detection is possible with an appropriate scouting program.

The development of an integrated pest management program in the Winter Garden would reduce insecticide use.

Proposed Program Strategy

An integrated pest management program in the Winter Garden should focus on the four main field crops: peanuts, corn, sorghum and cotton. The following discussion relates to program goals for these particular crops.

CORN:

Both white and yellow corn are grown in the Winter Garden. Its primary use is for corn chips, tortillas and other commodities used in Mexican food. Much of the corn acreage has been repeatedly planted to corn for up to 20 years, a practice that has led to severe infesta-

tions of the western corn rootworm. This insect reached damaging populations during 1976, when approximately 10 percent of the corn acreage was affected. Some fields suffered losses of up to 90 bushels per acre. Medina County was one of the hardest hit. Since that time, area-wide demonstrations of proper chemical selection, placement of chemicals and advantages of rotation have been conducted. Rotation can eliminate the western corn rootworm from a field, but producers may not know which alternate crops to plant. Crop rotation with irrigated sorghum would not be economical, and producers in this area are not accustomed to growing cotton. The best possibility is a rotational cycle using corn wheat, soybeans, then corn again. This would not only eliminate the corn rootworm, but also would provide additional nitrogen for corn.

Producers who cannot rotate their corn should control the adult beetles when they average one beetle per plant. This prevents egg laying in the fields and effectively controls the western corn rootworm the following year. The main drawback to spraying for beetles is that it destroys the beneficial arthropods and usually results in a damaging infestation of the Banks grass mite. This important pest is resistant to most chemicals.

Producers in the Medina County area could be taught to grow short season cotton as a rotational crop. They are relatively close to a cotton gin, and cotton would be an excellent rotational crop for Johnsongrass and western corn rootworm control in corn. An Extension agent-entomology (PM) could develop programs to educate producers in all aspects of cotton production. A corn-cotton rotation could be beneficial both economically and entomologically.

COTTON:

Cotton producers in the Winter Garden area need an integrated production system that includes all agroeconomic and economic aspects of growing the crop. Important elements of the system would be irrigation timing, nitrogen rates and control of overwintered boll weevils. The benefits of short season cotton are realized in net returns, not in gross production. It is a fact that lower yields can, at times, be more profitable if inputs are lower.

Short season cotton production has many advantages, such as:

- 1) Early destruction of stalks to prevent excessive build-up of the boll weevil.
- 2) Lower production costs.
- 3) Decreased exposure to the resistant budworm.
- 4) Early harvest before late August and September rains can damage crops.
- 5) Reduced insecticide use.

Superior short season varieties are available which produce excellent quality cotton and yields. Short season production should be encouraged.

SORGHUM:

A cotton-sorghum rotation helps control cotton root rot and bollworms, and reduces Johnsongrass problems in sorghum.

Sorghum insect problems seem to have increased in recent years; at least, growers are using more insecticides than they once did. An integrated pest management system would strive to prevent unnecessary treatment of sorghum. The need for insect and disease resistant varieties should be stressed in educational programs.

PEANUTS:

Peanuts often are given unnecessary insecticidal applications to control thrips and certain foliage feeding insects. A pest management program for peanuts would deal with these and other insects, as well as disease detection and control. Producers need a systematic approach to controlling soil-borne diseases, and rotation systems for lessening the severity of certain leaf spot diseases.

Southern blight has been a perennial problem in Frio County, and the pest management program could help to control this disease. Climatic measurements, air drainage of fields and hydrothermograph readings in each field would provide scouts with data on which to make management decisions.

The major goals for a peanut pest management program would include:

- 1) Less pesticide use on non-economic thrips infestations.
- 2) Weather monitoring programs to promote timely fungicide applications.
- 3) Correct disease diagnosis and the proper selection of fungicides.
- 4) Burrowing bug detection and management.
- 5) Management of soil-borne diseases.
- 6) Investigating the use of PCNB for disease control in some fields.

Program Organization and Extension Needs

Program organization and Extension needs are the same as described for the Lower Gulf Coast.

Research Needs

CORN:

Entomological research on corn is lacking in the Winter Garden. A corn research entomologist is needed to formulate pest management strategies with special emphasis on the western corn rootworm.

Currently, most control tactics for this insect are modifications of mid-west U.S. technology, and are neither feasible nor effective in this area. Furthermore, the insect has already become resistant to commonly used organic-phosphorus and carbamate insecticides.

The following are research priorities related to corn insect management in the Winter Garden:

- 1) Investigation of cultural practices that influence the western corn rootworm and other pests.
- 2) Determination of damage tolerance levels, including economic thresholds.
- 3) Biological and ecological studies of corn insect pests.
- 4) Studies of insecticide efficiency, timing and application methods.
- 5) Evaluation of the use of corn rootworm resistant varieties.
- 6) Evaluation of the role of corn and corn insect pests in a total crop production system for the Winter Garden.

COTTON:

Research on short season cotton production is needed, including:

- 1) The influence of planting dates.
- 2) The timing of applications for overwintered boll weevil control, the number needed and a cut-off date for applications.
- 3) The likelihood of bollworm/budworm attack following untimely insecticide application in the early season, and methods of managing secondary attack.
- 4) The effect of short season production on area-wide overwintered weevil populations.
- 5) Diapause weevil control.
- 6) Water management.
- 7) Nitrogen and phosphorous fertilizer requirements, and best application method.
- 8) Improved varieties.

During the next 5 years, a number of research areas should be expanded. They are:

- 1) Maximizing the benefits of beneficial arthropods in sorghum.
- 2) The value of frego bract in preventing weevil damage and reducing pesticide treatments.
- 3) Using boll weevil pheromone to detect and measure weevil activity.
- 4) Understanding the spring and summer movement of the weevil.
- 5) The value of glabrous and high gossypol in cottons in preventing bollworm/budworm attack.
- 6) The importance of cotton aphid and thrips control.
- 7) The importance of alternate hosts of the weevil.

Available insecticides should be continually evaluated, including those that might be needed for late season protection.

SORGHUM:

The needs for sorghum research are the same as those described for the Lower Gulf Coast.

PEANUTS:

Major peanut diseases are *Pythium* pod rot, leaf-spot, leaf blotch and rust. These diseases are managed primarily through the prophylactic use of fungicides. Present research programs are aimed at evaluating new fungicides, evaluating varieties for resistance, studying biological disease control and determining the non-target effects of fungicides.

Major insect pests are burrowing bugs and cotton bollworms. With the vast plantings of runner type peanuts, potato leafhopper damage has caused yield reductions. Pesticide use for this insect is increasing at an alarming rate.

Peanut research needs include:

- 1) *Pythium* and leafspot resistant varieties.
- 2) Biological disease control and the non-target effects of fungicides.
- 3) The ecology and management of burrowing bugs.
- 4) The economic impact of potato leafhopper on runner type peanuts.
- 5) Biological control of the cotton bollworm.

Program Evaluation

Evaluation will follow the outline in the preceding section.

Regulatory Needs

Pink bollworm regulations state that all cotton should be planted between March 5 and May 10, and stalks destroyed by October 10.

These requirements are inappropriate for satisfactory boll weevil management; therefore, it is recommended that cotton be planted between March 1 and April 15, and all stalks destroyed by September 15. A plow-up date of September 15 should be mandatory. The following are suggested as possible vehicles for encouraging stalk destruction and/or fall insecticide application: a) popular adoption of a Commodity Referendum Law detailing the required needs; and b) automatic deduction of sufficient funds from individual yield receipts to cover stalk destruction costs the following year. If stalk destruction is not completed by the required date, it is suggested that forfeiture of funds be automatic. If cotton is not planted by April 15, an alternate crop should be grown. Late or replanted cotton is usually disastrous for producers.

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RIO GRANDE VALLEY PEST MANAGEMENT PLAN

Cameron, Hidalgo, Starr and Willacy counties are located along the Rio Grande River in the extreme southern tip of Texas. The area has a subtropical, semi-arid climate characterized by short, mild winters and long, hot summers. The growing season is long, averaging 330 days per year. Cotton is one of the principle crops, with an average of more than 400,000 acres planted in the past 3 years.

The legally regulated cotton growing season is February to August 31st. Most fields are planted during the first 10 days of March, which allows a growing season of 160 to 180 days. Most of the acreage is planted to long season determinate varieties, and about half the acreage is irrigated. Practically all cotton is harvested with spindle pickers and has an average yield of 430 pounds of lint per acre. However, yields of up to 750 pounds per acre are common. In many cases, attempts to obtain maximum yields result in excessive nitrogen use, late irrigations and heavy insecticide applications. These practices tend to delay maturity and may expose cotton to heavy late season pest attack. Late harvest also increases the probability that yields will be reduced by adverse weather conditions.

Major cotton insect pests include the cotton fleahopper, boll weevil and cotton bollworm/tobacco budworm complex. Insecticide applications on dryland acreage generally range from zero to eight per year. On irrigated cotton, applications range from six to twenty; most fields are treated eight to twelve times.

Under the existing extensive chemical control program, losses are about 15 percent for all cotton insects, with 5 to 6 percent caused by the boll weevil. As the Rio Grande Valley Cotton Pest Management Program has demonstrated, sound pest management will either reduce the number of insecticide applications and/or result in higher yields. This provides a wider profit margin for producers. Current fixed production costs range from \$40 to \$50 per pound of lint in the Valley.

Proposed Program Strategy

Cultural

Since the management of insect pests is closely related to the management of the crop itself, certain farming practices are essential if pest management is to be successful. The importance of early crop maturity

cannot be overemphasized. Several new cotton varieties, if planted early and managed properly, offer earlier crop maturity for producers in the Rio Grande Valley. Among these are the TAMCOT SP varieties. Early crop maturity will aid in pest management by reducing boll weevil populations, thus delaying damaging infestations the following spring. By delaying insecticide applications through proper IPM scouting, outbreaks of bollworms and tobacco budworms may be reduced. For these reasons, producers should be encouraged to use agronomic practices which hasten crop maturity.

Cotton should not be planted later than March 31. Producers should be required to completely destroy plants, including regrowth of stubble and/or seedlings, so as to have a cotton free period from August 31 to February 1. If weather conditions prevent plant destruction by August 31, chemical killing of cotton is recommended. Or, if this is not practical, then insecticide treatments should be applied until plants are either destroyed or killed chemically.

The excessive use of nitrogen and irrigation water should be avoided. Irrigation should be terminated early enough to prevent excessive growth, and to ensure an early harvest before late summer and early fall rains.

Early Season Pest Management

Spring insecticide applications for overwintered boll weevils should be used on individual fields as recommended by entomologists or supervised scouts.

Insecticides for early season control of the cotton fleahopper should be used on the basis of insect numbers and fruit loss as indicated by field inspection.

Mid-Season Pest Management

Mid-season control of the boll weevil, cotton bollworm and/or tobacco budworm should be based on insect numbers and fruit loss. The timing of insecticide applications is extremely critical when controlling the cotton bollworm and the insecticide resistant tobacco budworm.

Late Season Pest Management

To suppress fall boll weevil populations, it is suggested that insecticides be applied at the time of defoliation or near the plant destruction deadline until plants are destroyed.

Program Organization and Extension Needs

The Rio Grande Valley Cotton Pest Management Program should be continued in Cameron, Willacy and Hidalgo counties. This program has proven to be highly successful in increasing the net profits of its participating producers. Of equal importance, the program has provided Valley-wide insect and cropping information and stressed the value of pest management in educational programs. These educational activities should be continued. More intensive efforts to keep private entomologists, cotton and grain producers and agricultural industry personnel better informed on current insect situations will be needed. Information will be disseminated through producer newsletters and daily radio reports.

Producers will be encouraged to use qualified consultant entomologists, and these entomologists will be provided with advanced training and educational materials developed from research and pest management programs.

Producers participating in the Rio Grande Valley Cotton Pest Management Program will be asked to pay scouting costs based on their acreage scouted. The number of acres scouted will increase as qualified scout supervisors and scouts are hired and trained.

The Rio Grande Valley Cotton Pest Management Program will work through the Texas Pest Management Association and with the Cotton and Grain Producers Association of the Lower Rio Grande Valley.

The Texas Agricultural Extension Service will be responsible for educational programs. Various aspects of the educational effort should include: 1) cotton insect scouting schools; 2) producer meetings in each county involved; 3) daily cotton insect reports for radio and television; 4) weekly insect newsletter; 5) specific news releases; 6) television programs; 7) field days in cooperation with Rio Farms, USDA and Texas Agricultural Experiment Station; 8) the BUGNET program; and 9) pesticide applicator training and safety programs.

A liaison program with APHIS and Sanidad Vegetal in Mexico should be established to keep abreast of cotton pest trends in the area south of the Rio Grande Valley.

Research Needs

COTTON:

Short season cotton production systems in the Lower Rio Grande Valley are being researched. These systems, using short and intermediate season varieties, have produced yields comparable to conventional production systems and have reduced insecticide, irrigation and fertilizer usage and, thus, overall production costs. Result demonstrations will be continued to emphasize the benefits of these improved management systems. Economic thresholds for insects on narrow row and short season varietal plantings should be established.

Research is needed to provide information on the following topics: 1) the overwintering and diapause

habits of the boll weevil; 2) the effectiveness of pheromones, insecticides and/or trap crops for suppression of overwintering boll weevils; 3) the threshold levels for all cotton insects, especially on short season cotton varieties; 4) the usefulness of plant growth regulators in enhancing early maturity; 5) the use of remote sensing to locate "hidden" cotton fields; 6) methods of destroying regrowth cotton during periods when fields cannot be cultivated; and 7) proper irrigation and fertility practices for optimal production of the new and currently grown varieties.

SORGHUM:

Grain sorghum production in South Texas continues to increase, with parallel increases in insect damage and insecticide use.

The environmental and ecological relationships influencing sorghum insect pests in the Lower Rio Grande Valley differ significantly from those in other parts of Texas. Consequently, there is an urgent need for sorghum insect research to formulate pest management systems applicable to this essentially tropical area.

Research dealing with early, uniform planting should be stressed. Valley soils are basic and tend to cause iron chlorosis in sorghum. This delays maturity and causes uneven bloom, thus prolonging exposure to the sorghum midge. Research could solve the iron chlorosis problem. The development of tropically adapted and insect resistant varieties also should be continued.

Double cropping or fall planting of sorghum in the Lower Rio Grande Valley would increase producers' revenue if research could provide a way of controlling the sorghum midge. Sorghum midge resistant sorghums used along with other control tactics might be the answer. Additional biological and ecological research is needed to better define the population dynamics of the sorghum midge.

The yellow sugarcane aphid and sugarcane rootstock weevil are of increasing concern in the Lower Rio Grande Valley, and must be dealt with if economic sorghum production is to continue. Research should develop management strategies for these pests, and determine their relationships with sugarcane and other host plants.

The close relationship of sorghum and the perennial weed Johnsongrass, with respect to insect pest complexes, urgently needs to be studied. There is an increasing incidence of damaging midge and yellow sugarcane aphid infestations developing from Johnsongrass.

Researchers also should determine the relationship between sorghum and cotton with respect to weed control and the interchange of insect species.

Program Evaluation

The success of the program will be determined through an annual economic and environmental evaluation, and a survey of changes in producer attitudes

and pest management practices. Evaluations will point to areas where improvement is needed.

Regulatory Needs

There are mandatory planting and stalk destruction dates for control of the pink bollworm. These regulations can be very helpful in controlling boll weevil populations, but only if practiced area-wide.

Citrus Integrated Pest Management Plan

Citrus acreage in Hidalgo, Cameron and Willacy counties as of January 1, 1979 totaled 75,900 acres. Approximately two-thirds of this area is competitive with other production zones, primarily because of the excellent internal and external quality of the fresh fruit. Many, if not most, producers could not survive in the industry if incomes were based on processed rather than fresh market prices. Therefore, strong effort is made to minimize fruit blemish.

Insects and melanose disease are the principle causes of fruit blemish. In their efforts to prevent damage, producers employ a variety of pesticides, application schedules and application techniques. Frequently, little or no thought is given to pesticide effects on beneficial organisms, with the result that secondary pests develop to damaging levels and require additional chemical treatments. Beneficial insects also may be destroyed when undesirable spray materials drift from adjacent cotton and vegetable fields to citrus groves. Spraying of pesticides, particularly when large acreages are involved, often is done on the basis of a predetermined schedule, rather than as needed, to permit maximum utilization of expensive spray equipment. Also, criteria used for determining when to spray for the citrus rust mite and other blemishing agents are too crude at present to contribute greatly to refined pest management techniques.

Melanose, a disease caused by a fungus present in all mature citrus groves, causes a high percentage of blemished fruit under favorable environmental conditions, and is especially severe in unpruned trees. The present trend toward close plantings and mechanical hedging of trees rather than hard pruning is expected to increase the severity of this disease. Fungicides applied for melanose control are lethal to *Hirsutella thompsonii*, the most important biological control agent for the citrus rust mite. Growers may also use Zineb, a fungicide with miticidal action, to control rust mite.

An estimated 10 to 15 percent of the total fresh fruit crop annually suffers grade losses caused by blemishes. The use of inappropriate chemicals, poor timing and inefficient application techniques further reduces producers' profit margins. A sound program of pest management, integrating the latest knowledge of cultural, chemical and biological control techniques, will

reduce the amount of pesticides used and result in higher yields of better quality fruit.

Program Strategy

Cultural

Certain cultural practices have a direct influence on pest populations. These will dictate, to some extent, pest management strategies. Because atmospheric humidity is an important factor in the development of pest and beneficial populations, high density plantings, weed control, irrigation frequency, pruning practices and varieties used all have an impact. Use of these cultural practices will be recorded during appropriate grove monitoring periods, and the accumulated data from a variety of cultural situations evaluated for refinement of pest management techniques.

Chemical

Certain insecticides, fungicides and nematicides will be evaluated in demonstration groves to determine their efficiency in relation to amounts used, ideal timing and method of application and their effects on target pests and beneficials. Data will be accumulated at bi-monthly or monthly intervals throughout the crop year, and evaluated to help in making future pest management decisions.

Biological

Citrus groves in the program will be monitored periodically with special attention to pest populations, populations of beneficial organisms and environmental conditions. Control procedures will be based on the kind and number of pests present in relation to beneficials. Emphasis will be placed on management of rust mite, scale insect pests and melanose disease, using specific narrow spectrum chemicals or oil whenever control is warranted. Relative cost of materials also will be considered in making chemical choices. Locations of monitoring sites will be representative of the major production zones in order to enhance awareness of the program and its future expansion. Whenever possible, sites for the Pest Management Program will be selected on the basis of owner-producer willingness to place a portion of his acreage in the program while retaining a portion under customary practices. This permits a direct comparison of fruit quality, yield and economy of production.

Educational Needs

The Texas Agricultural Extension Service will be responsible for complementing demonstration and monitoring efforts with educational programs. These include: 1) training programs in identification of pests and beneficial organisms; 2) producer meetings; 3) timely radio and news articles relating to current pest situations; 4) informative letters to cooperating producers; 5) tours of demonstration projects; and 6) use of monitoring data to increase producer awareness and acceptance of monitoring procedures as a guide in making pest management decisions.

Research Needs

Research is needed in the following areas:

- 1) Systemic chemical treatment for control of root rot (*Phytophthora* fungi).
- 2) Integrated control methods for greasy spot disease.
- 3) Reliable sampling techniques for the citrus nematode.
- 4) Economic threshold levels for the citrus mite.
- 5) Efficacy of low volume spray equipment in pest control operations.
- 6) Prediction of melanose outbreaks in citrus.

BUGNET—A COMPUTERIZED PEST MANAGEMENT INFORMATION DELIVERY SYSTEM IN TEXAS

In this technological age, the knowledge available to researchers is monumental. The ability of researchers to make useful agricultural forecasts is becoming more advanced. Forecasting requires sophisticated computer technology and the availability of a variety of data.

The timely delivery of useful information to growers is a difficult task. Many approaches are possible, and other universities and private firms have implemented a variety of projects. The choice of solutions is complicated by the fact that computers continue to develop rapidly, so that the machines available today are likely to be obsolete within a few years. Thus, the versatility of future machines must be considered in the development of a successful system.

The use of computer technology in pest management is dependent on four main components: 1) research and modeling of the pest, the host crop and the climate; 2) biological monitoring; 3) environmental monitoring; and 4) an information delivery system to educate and communicate. Each component of the system is dependent on the others for completion of the task.

Entomologists, plant physiologists and other research scientists provide the data, concepts and theories in the form of basic system behavior models. The next step is the development of mathematical models which can be used specifically to predict such events as insect pest population densities, fruiting patterns of the crop, crop yields, etc., which normally affect pest management decisions. Then predictive models of various pests, the host crop plant, the physical environment, etc., can be used to predict future occurrences of pests, their damage to the crop and the resulting crop yield potential.

Such a computer forecasting system could take some of the uncertainty out of agricultural production. For example, the computer could supply updated information on approved insecticides, their application rates for various cotton insects, fertilizer rates, etc., upon request. As Purdue University (Indiana) entomologists in charge of a computerized forecasting system for alfalfa insect pests commented, "The farmer will find that this system is like having half-a-dozen agricultural specialists sending a telegram to him in immediate response to his request."

The BUGNET system, devised by the Texas Agricultural Extension Service, includes an entire information delivery system with hardware (equipment), software (computer programs) and personnel. The hardware is a network of minicomputers strategically

located around the state. The software is tailored to the hardware, to some extent. In designing the software, every effort must be made to make the programs as easy to use as possible.

Area and county Extension staff members are the primary users of the BUGNET system. They inform producers about the system at field days and in office visits, and also distribute regional predictions via mass media.

Objectives of the BUGNET system are:

- 1) To provide county Extension agents with data upon which to base pest management recommendations.
- 2) To help producers improve pest management decisions and hence long-term profits, while preserving the environment.

The system will demonstrate to producers, pest management consultants and Extension personnel the capabilities of computer technology in pest management and test the cost effectiveness of this approach.

History of BUGNET

The early plan for this project was developed by 1975. An expanded plan, completed in 1976, specified the steps to be taken, and suggested software applications and implementation dates. The initial computer purchase request was initiated at the same time.

Computers were delivered in August of 1977. Software was rapidly developed, and by spring of 1978 a few programs were in use.

Since that time, many additional programs have been completed, and new ones are in preparation at all times.

In 1979 an expansion of the computer system was planned. This plan called for the purchase of three new machines and the upgrading of old machines. All machines should be identical so that software and data can be exchanged easily.

Present State of the Project

Several deficiencies in computer capability, manpower and time projections were identified during the early years of BUGNET. Also, certain software items were found to be not very useful or feasible.

The IBM 5100, the original BUGNET computer model, proved to be too slow for some applications. The bollworm/tobacco budworm model, for example,

took nearly 2 hours to run; this limited its usefulness during critical times in the season.

The present hardware system consists of seven IBM 5110 minicomputers located at Lubbock, Vernon, Dallas, Stephenville, Weslaco, Corpus Christi and Fort Stockton. Each minicomputer has a small CRT (television-type screen), a keyboard and a built-in cassette tape drive. Other attachable equipment includes printers, floppy disk drives and acoustic couplers. These machines are used primarily as stand-alone computers, and only occasionally as terminals. Other hardware at the headquarters site is used for software development.

Internal computer core storage is a continuing limitation of the system. For example, the bollworm model is limited to a 90-day prediction beyond the first square date. With extra core storage, 120- to 150-day predictions would be feasible. Also, computer applications could be prepared more quickly. At present, applications must be programmed around the core limitation.

Magnetic tapes, the original data storage means, were slow and cumbersome, and have been replaced by floppy disk units. The new system lends itself to information retrieval, such as recalling pesticide recommendations or pest distribution information.

In the past, individual software items were distributed on separate tapes. With floppy disks, several applications can be consolidated on one disk, thus eliminating handling and storage problems.

Since all applications have a consistent input format and error checking method, staff training has been easily accomplished. Most staff members have had only minor problems after a few hours of training. Additional training probably will be necessary as hardware is upgraded.

Although it is time consuming to move the computers to different sites, they are portable and can be used at field days, in producers' homes or wherever needed. The Extension office is the permanent location for some of the hardware like the floppy disk drive. However, the tape drive can be used as the storage unit during remote demonstrations.

The software determines the success of a project such as BUGNET. All BUGNET software is designed so that the user needs very little knowledge of computers or programing. All the user has to do is insert the correct computer tape, turn on a switch and issue one command. After that, he simply responds to questions asked by the program. This type of software, known as interactive programming, has been the key to BUGNET's success.

However, the software is difficult to develop. Much more time is required to make it error-proof and consistent than was anticipated. Substantial time is required to provide the user with data that is readable and consistent.

BUGNET now has several significant applications in operation, and more are being scheduled. Current applications range from complex computerized models, to sophisticated computerized games, to information-recall programs. Most are designed to aid in decision making or education, and all can help

producers become better managers. The following is a brief summary of the principal BUGNET applications (computer programs).

Enterprise Budget Simulator

The enterprise budget simulator lists current cotton budgets, developed by Extension economists-management, for more than 20 production areas in Texas. These areas are delineated by major soil types. The budgets itemize production costs and show estimated gross and net returns. The main purpose of the enterprise budget simulator is to help a producer modify an existing budget so that it more closely fits his geographical location and production practices. Newly revised budgets can be stored on computer tape for future reference. However, the budget simulator is currently capable of modifying cotton budgets only for selected areas.

The enterprise budgets are based on estimates of yields, prices, production input quantities, input prices and production practices. These estimates represent the best judgment of local producers, county Extension agents-agriculture, financial institution representatives, farm machinery dealers and other knowledgeable persons. Variations in yields and production practices for particular farms should be expected.

The information provided by the budget simulator should help the producer plan and develop future operations to obtain the full potential of land, labor and capital resources, thus improving the economic efficiency of his business.

MOTH-ZV *Heliothis* Model

The MOTH-ZV *Heliothis* Model accurately predicts bollworm, *H. zea*, and tobacco budworm, *H. virescens*, populations in cotton. The model can be used on a field-by-field basis or on an area-wide basis. Used on a field-by-field basis, it can be a very reliable indicator of actual population densities. If used for a larger area, it is only reliable in predicting population trends.

Input for the model consists of daily insect trap catch records and daily high-low temperatures. Insect traps used are general purpose blacklight traps (for monitoring bollworm) and special purpose pheromone traps (for monitoring budworm). These pheromones are sex lures which attract male budworms. The tobacco budworm pheromone Virelure® has been used successfully for several years. A pheromone for bollworm, Zealure®, has been recently developed but not fully tested. If testing proves this pheromone successful, both insects can be monitored with the easy-to-use pheromone traps.

The MOTH-ZV *Heliothis* model produces a graph reflecting population fluctuation and densities over a period of time. Eggs, first through third instar larvae (small worms), and fourth and fifth instar larvae (large

worms) are plotted. The model can predict population movements up to 90 days in the future with a fair degree of accuracy.

It is important to note that control decisions should not be based on the results of this model alone. This model should be used in conjunction with a good scouting program, and producers should be sure that damaging numbers of bollworm/budworm are imminent before initiating any control measure.

Cotton Pest Management Decision Game

The cotton pest management decision game simulates cotton production for one growing season. This game requires that the user control two major cotton pests, cotton boll weevil (*Anthonomus grandis*) and bollworm (*Heliothis zea*), with judicious use of insecticides. This is done by simulating the growth of the cotton crop and the population dynamics of these two pests. Economic thresholds for each pest are incorporated into the game. These threshold levels are taken from *Management of Cotton Insects in South and East Texas Counties* (B-1204).

Games such as this are valuable primarily as educational tools. The game simulates actual field conditions fairly well and gives the user an idea of what can happen in the field. It also presents the user with the information he or she needs to make a control decision, and increases user awareness of important factors affecting management decisions.

Such games also can serve as an introduction to computer technology, and illustrate to users the value of such technology in agricultural management.

Emergence Distribution Model

The emergence distribution model can predict from a cohort of eggs:

- 1) the date the first adult will emerge;
- 2) the date the last adult will emerge;
- 3) the daily percent of adult emergence; and
- 4) the peak of adult emergence.

This model is applicable to boll weevil (*Anthonomus grandis*), bollworm (*Heliothis zea*), and cotton flea-hopper (*Pseudatomoscelis seriatus*).

Computer input is the date of egg lay (usually known from sampling), the species of insect and daily high-low temperatures. No specific monitoring techniques are used to determine egg lay date, and the number of eggs laid is not important.

Output of the model is a graph depicting the daily percent emergence from one cohort of eggs. That is, if you tell the model what day a cohort of eggs was laid, it will tell you when these eggs will develop into adults. This development may take several days, since all eggs do not develop at the same rate.

This model is just part of a more comprehensive population model. It should not be used as the sole basis of making a management decision, as eggs are generally laid over a period of several days and the model does not blend two or more cohorts together to

reflect a total population. Its main value is educational.

Boll Weevil Model

The boll weevil model predicts population densities and dynamics of the boll weevil, *Anthonomus grandis*.

Input consists of: the date the first overwintered adults migrate into cotton; daily numbers of adults migrating into cotton; the date of planting; daily weather data; and the date the first one-third grown squares appear.

Output consists of several graphs. One shows predicted first generation boll weevil emergence in the field. Another reflects predicted boll weevil damage if no control measures are taken. This model is fairly new and has not been thoroughly tested under a wide variety of field conditions. It should be used in conjunction with a field monitoring program.

Peanut Leaf-feeder Model

This program predicts the percent defoliation and maximum percent yield loss in peanuts caused by corn earworm, yellow striped armyworm, beet armyworm and fall armyworm. The prediction uses data developed by Dr. J.W. Smith, Department of Entomology, Texas A&M University. The model is based on a typical, irrigated peanut field, and normally should not be used for nonirrigated fields. Caterpillar populations are sampled in the field, and this data is fed into the computer. (Caterpillars other than the four main species are counted with corn earworms.) There is no provision for migrations or additional generation build-up. Therefore, the model is accurate only for short-term population predictions of about a week.

Pecan Pest Management Decision Game

This computer game is designed to teach pest management principles as they relate to pecan production. The object of the game is to manage pecan nut case-bearer and pecan weevil, two major pecan pests, with precise timing of insecticide applications.

The game simulates actual field conditions fairly well, and acquaints the user with vital information needed in making control decisions.

BUGNET Plotting Package

This package allows the BUGNET user to plot data and manipulate it in various ways for better interpretation. A single set of data, or a combination of several sets of data, can be plotted. Other capabilities are the smoothing of data, the conversion of day/month to Julian Day, and filling in for missing data.

While the BUGNET plotting package can be used for educational and decision making purposes, it is intended solely as a utility package.

Future Plans

Development of new software is dependent on available manpower. Some projects underway include a pecan weevil model, a Southwestern corn borer model and pesticide information retrieval. Existing software will be revised according to the capability of the new IBM 5110 machines. A mailing list program is now feasible and the pesticide compatability program would now be worth updating. Additional professional staff and programmers are needed to keep applications current and develop new ones.

BUGNET was initiated by members of Biosystems Research Division and the research entomologists at Texas A&M University. They saw the feasibility of using computer models to help solve pest problems in the state of Texas. Extension entomologists have made the computer applications developed by research available in the field.

A very close working arrangement has been maintained between Biosystems Research Division and

Extension personnel involved in BUGNET. Biosystems Research Division helps in the development and implementation of crop and insect models, and recommends computer hardware systems to be used in BUGNET. The Biosystems group also helped adapt the software for personnel who are not computer oriented by developing input correction techniques and special commands. The involvement of such highly qualified computer professionals must be maintained.

In addition, Extension entomologists and other specialists who have knowledge of computers are needed to solve problems and generate software. It has been difficult in the past to maintain manpower because of salary structures and the discontinuity of research funding. This project requires high levels of funding from both the Texas Agricultural Extension Service and the Texas Agricultural Experiment Station. Since the responsibilities of research and Extension frequently overlap in a project of this nature, administrators should make appropriate salary adjustments.

THE ROLE OF THE PRIVATE CONSULTANT

Members of the Texas Association of Consulting Entomologists were asked to review and comment on A Statewide Pest Management Plan for Texas. Recognizing that consultants play a vital role in the advancement of integrated pest management, the following statement was provided by their Association. This statement is not meant to reflect the attitudes or orientation of private consulting entomologists not affiliated with the Texas Association of Consulting Entomologists.

"The designers of the 'state plan' recognize the establishment of the private practitioner in agriculture. Since 1974 many private practices have been established, and new businesses and older firms are adding professionals at an increasing rate. Many of these people are highly skilled, trained, and expe-

rienced IPM practitioners. The state association (Texas Association of Consulting Entomologists) and the national organization (National Alliance of Independent Crop Consultants) are made up of individuals who are screened by training, experience, and ethical standards.

"Every effort will be made to promote the private practitioner in Texas. Programs will be coordinated with private consultants in order to promote rather than interfere with this fledgling profession. The TACE and the NAICC are the only organizations of qualified, on-the-farm, private practitioners at this time. The help of these organizations in designing and implementing the various IPM programs to benefit the Texas farmer is greatly appreciated."

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TEXAS AGRICULTURAL EXPERIMENT STATION LONG-RANGE PLAN

The Texas Agricultural Experiment Station has assessed its current research program and projected research needs for the next 5 years. The long-range plan developed by the Texas Agricultural Experiment Station is being used to set research priorities and track accomplishments. Several sections of the plan discuss research needs for integrated pest management, and reflect the interdisciplinary activities involved in total crop production systems. Input from commodity associations and farmer groups ensures that the plan will truly reflect statewide research requirements.

The concept of integrated crop management is developed within the plan. Integrated crop management is defined as the development of cropping systems which use various plant cultivars, along with appropriate cultural practices, in order to generate optimum yields under a range of environmental adversities. Environmental adversities include pest and weather stresses. Integrated pest management is, of course, part of integrated crop management. The goal of current and future research, then, is to develop integrated crop management systems in which pest populations are kept below economically damaging levels.

The Texas Agricultural Experiment Station Long-Range Research Plan specifies several areas of research needs, such as developing pest resistant varieties, studying the effects of cultural practices on pest management; improving economic thresholds through increased knowledge of pest biology and damage, and developing new pesticides. The use of biological control methods must also be studied. General research needs include studying the economic effects of integrated pest management and preventing environmental damage caused by mis-use of pesticides.

Both the Texas Agricultural Experiment Station Plan and the Statewide Pest Management Plan are based on a systems approach to research and the implementation of research findings. With a systems approach, research from all disciplines which affect crop management can be integrated, and problems frequently can be anticipated and thus dealt with more easily. A systematic approach to crop production also considers the crop's relationship with other crops and with the surrounding environment. This method, sometimes termed ecosystems analysis, provides greater knowledge of the interactions between pest species (insects, weeds, diseases and nematodes) and

their relationship to crops, weeds and other vegetation. The role of natural enemies, along with other mortality factors, must be considered in determining their role in pest population regulation.

The following paragraphs review research needs from the Texas Agricultural Experiment Station Long Range Plan as they relate to major crops.

COTTON AND COTTONSEED

The overall goal of research is to improve the cost/return ratio of cotton production in Texas. Specific goals include: 1) developing improved production systems for the Rolling Plains and west Central Texas, and an improved short season production system for the Lower Rio Grande Valley; 2) modifying cultural systems in relation to soil and water conservation, irrigation scheduling on saline soils and row configuration; 3) improving the management of irrigated cotton; 4) breeding cotton varieties with improved tolerance to drought and temperature extremes; 5) breeding for improved cottonseed quality; 6) reducing cotton dust through better engineering; 7) understanding the effects of root environment on plant growth; 8) improving harvest aid chemicals and harvesting equipment; 9) developing disease and nematode resistant varieties; 10) managing phymatotricum root rot and nematodes; 11) using native and imported entomophagous arthropods (parasites and predators), as well as insect pathogens, for biological control; 12) manipulating insect populations through cultural control; 13) refining economic thresholds of key insect pests; 14) controlling overwintering boll weevils by habitat management; 15) evaluating insecticides; 16) managing annual and perennial weeds; and 17) determining the interactions of soil herbicide residues.

The economics of all current and new integrated crop management systems should be continuously evaluated. Also, Texas cotton production should conform to national cotton policy.

SORGHUM

Integrated crop management systems are devoted to improving the quality and quantity of sorghums in Texas. Research is planned for the following areas: 1) developing sorghums with improved tolerance to environmental stresses; 2) identifying, developing and adapting sorghum hybrids and parental lines for specific management practices in the Rolling Plains, West

and Central Texas, the Coastal Plains and the Rio Grande Valley; 3) converting exotic sorghum to shorter types for use in Texas; 4) employing useful sterility systems; 5) developing high grain and total carbohydrate production in subtropical lines, and incorporating low dhurrin levels; 6) studying the inheritance of plant and grain characteristics, especially those that influence root growth; 7) determining the influence of dryland cultural practices on sorghum pests; 8) improving dryland farming equipment; 9) exploring alternative grain and forage sorghum production systems; 10) investigating maturity, yield, water use efficiency and cultural practices (specifically land preparation); 11) defining the mechanisms of pest-geotype interactions; 12) developing sorghums resistant to diseases (especially head smut); 13) studying the effects of cultural practices on insects and mites, and the relationship between these pests and the physiological and biochemical state of the plant; 14) determining the impact of planting dates and alternative hosts on pest dynamics; 15) controlling occasional insect pests; 16) developing insect resistant sorghums; 17) controlling the greenbug, sorghum midge and Bank's grass mite with biological agents; 18) evaluating insecticides and improved application methods for sorghum midge control; 19) determining the role of arthropods as vectors of plant pathogens; 20) developing a sampling system for wireworm; 21) controlling annual and perennial weeds; and 22) studying the impact of herbicide residues in the soil on sorghum growth and development.

In addition, a comprehensive method of using systems analysis in sorghum production should be developed.

CORN

Integrated corn management stresses a systems approach for the maximization of profits. Fundamental to this system is the development of corn hybrids from elite inbred lines. Other research needs include: 1) studying the nutritive value of new hybrids; 2) improving the water use efficiency of corn hybrids; 3) developing alternative dryland corn production systems; 4) manipulating genetic control factors to suppress corn diseases; 5) rating of corn populations for pest resistance and regional adaptability to diseases, insects and mites; 6) studying insects as vectors of corn diseases; 7) controlling insects and mites, especially with biological methods; 8) establishing the damage potential for major corn insects; 9) developing an integrated weed management program; 10) preventing microbial and mycotoxin contamination of stored grain; and 11) controlling insects in stored corn.

WHEAT AND SMALL GRAINS

Research programs in wheat and small grains (oats and barley) should include: 1) studying water use efficiency and the interaction of available moisture and fertilizer; 2) studying the value of limited tillage and double cropping; 3) improving semidwarf wheat varieties; 4) incorporating high protein potential and

improved milling and baking qualities in food wheat; 5) developing wheats that are resistant to drought, lodging, wheat streak mosaic and other viruses, leaf rust and other foliar diseases and seedling root diseases; 6) developing disease resistant wheat germplasm; 7) predicting disease outbreaks; 8) developing rust resistant oat varieties and barley varieties resistant to barley yellow dwarf; 9) establishing economic thresholds for wheat, oats and barley; 10) controlling mites in wheat, oats and barley; 11) developing greenbug resistance in wheat and oat varieties; 12) controlling weeds under limited tillage production; 13) controlling specific weeds such as wild oats, brome species and other annual grasses; and 14) controlling perennial weeds and fall mustard in small grains.

Producers need improved marketing techniques for small grains, including better grain handling and transportation methods. Various grain marketing policies also should be studied.

RICE

Integrated crop management for rice requires research in several areas: 1) determining water requirements necessary to maximize yields and crop efficiency; 2) developing alternatives to flood irrigation; 3) developing high yielding, drought tolerant varieties that efficiently use soil and fertilizer nitrogen; 4) constructing a climo-physiological model for rice growth, development and yield estimates; 5) improving the table processing, cooking and nutrient properties of rice; 6) increasing rice anther culture and developing hybrid rice cultivars; 7) identifying the phosphorus fertilizer needs of rice; 8) developing a correlation between seedling physiological condition and yield potential; 9) using plant growth regulators in rice production; 10) improving energy conservation in rice mechanization; 11) developing disease resistant varieties; 12) developing a model that predicts the occurrence of diseases; 13) studying the role of rice sterility in kernel discoloration and the biology and control of kernel smut; 14) improving chemical application methods for disease control; 15) developing varieties resistant to the rice stinkbug; 16) studying the role of natural enemies (parasites, predators and pathogens) in suppressing insect pests; 17) establishing economic thresholds for all major rice insect pests; 18) determining the competitive effects of weeds on rice production; 19) controlling red rice; 20) evaluating herbicides and crop and herbicide rotational schemes; 21) developing cost and return budgets; 22) studying alternate energy sources in rice production; and 23) analyzing the economics of producing, marketing and distributing rice in the United States, along with the effects of the world rice supply, demand and trade policy.

In addition, researchers should study the biology, ecology and control of riceland mosquitoes.

SOYBEANS

Soybean production has increased dramatically over the last 5 to 7 years. Integrated crop management systems are needed to maximize soybean profits. Spe-

cific research needs include: 1) improving irrigation systems for low rainfall areas; 2) developing soybean varieties adapted to the High and Rolling Plains, Gulf Coast and South Texas; 3) developing seed quality acceptable for food processing; 4) improving nitrogen fixation and utilization; 5) reducing the effects of adverse soil conditions on germination and stand establishment; 6) developing disease resistant varieties; 7) using chemical and cultural methods for controlling diseases; 8) developing disease forecasting capabilities; 9) establishing economic thresholds for insect pests; 10) evaluating insecticides; 11) establishing the role and benefits of natural enemies in pest regulation; 12) investigating the biology and control of general weed species; 13) evaluating the selective use of herbicides in weed control; and 14) improving the economics of soybean processing and marketing.

PEANUTS

Peanut research should include: 1) improving the processing and marketing of Texas peanuts; 2) breeding peanuts for improved yield, cultural efficiency and quality; 3) studying the genetic variations of seed protein of peanuts and their close relatives; 4) upgrading varieties; 5) studying the factors affecting peanut nodulation and physiological properties contributing to yield; 6) studying water regulation and use efficiency in irrigated peanuts; 7) testing the maturity of peanuts to determine optimum timing of harvest; 8) using sprinkler application of fertilizers and pesticides; 9) managing soil-borne pathogens, nematodes and foliar diseases; 10) developing varieties resistant to soil-borne pathogens, nematodes, foliar diseases and aflatoxin-producing mold; 11) determining the nutritional requirements of peanuts and their relationship to pest resistance; 12) studying the plant stress factors leading to mold and mycotoxin susceptibility and aflatoxin production; 13) refining techniques for aflatoxin detection; 14) studying the susceptibility of various peanut varieties to pod diseases; 15) using systems analysis and computer technology to determine insect population dynamics; 16) developing insect resistant

peanut varieties; 17) using natural enemies for pest control; 18) evaluating insecticides and application methods; and 19) managing key weed species.

The potential market demand for southwestern peanuts should be analyzed, as well as the use of glandless cottonseed and peanuts in meat products.

PECANS

Pecan research is aimed at increasing productivity, and includes: 1) studying photosynthetic assimilation, chilling and day length requirements, flower inundation, root generation and optimum leaf surface for maximum pecan production; 2) improving irrigation systems; 3) developing a feasible means of tree size control and nut thinning; 4) improving pecan root stocks; 5) studying the nutritive value of the pecan; 6) managing diseases; 7) studying mycotoxin contamination; 8) controlling nematodes; 9) determining appropriate timing of insecticide applications from refined economic thresholds; 10) using insect control; 11) using herbicides for weed control in pecan orchards; 12) studying the economics of pecan production and marketing; and 13) developing a price-supply strategy to improve market development for this Texas commodity.

CITRUS

Specific citrus research needs are: 1) improving citrus and subtropical scion varieties; 2) improving cultural practices; tree management and mechanization of production; 3) reducing freeze injury and other environmental hazards; 4) developing an integrated approach to the management of disease and nematode pests; 5) studying and controlling major weeds; and 6) analyzing the economics of production, handling and marketing.

The Texas citrus industry has an established and successful integrated pest management program for the control of insects and mites. This valuable program should be expanded.

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TEXAS AGRICULTURAL EXTENSION SERVICE PROGRAM THRUSTS FOR THE 1980'S

In keeping with the mission of the Texas Agricultural Extension Service, dynamic programs in the area of integrated pest management have been developed to improve productivity and profits for agricultural producers. The Texas Agricultural Extension Service has organized an extensive long range planning activity for the 1980's — *The Extension Way: People Helping People*. In response to a survey of community leaders and Extension personnel, 130 program area plans were developed by Extension specialists to meet educational requirements for the 1980's. A manual was written to help Extension and its clientele plan educational programs and measure accomplishments. This comprehensive manual identifies six major concerns: energy; economic conditions; land and water resource management; social conditions; marketing and policy; and leadership development. The objectives of integrated pest management programs are interwoven with each of these major areas.

The availability and economics of energy resources affect agricultural production and integrated pest management programs. Changing economic conditions, particularly inflation, influence all phases of

production. IPM programs are designed to decrease production costs, increase yields and, in turn, increase net profits of participating farmers. Records show that the Statewide Pest Management Program is achieving these goals. The conservation of land and water resources also is an important factor in the economics of integrated pest management.

Integrated pest management is contributing to improved marketing of Texas agricultural commodities. Texas farmers are in a better position to market more effectively and develop policies for their commodities. The organization of county, regional and statewide committees provides a leadership base for pest management programs. Without the leadership of interested farmers across the state, the Statewide Pest Management Program would not have achieved its outstanding success.

The Statewide Pest Management Plan was developed simultaneously with Extension's planning manual for the 1980's. The Statewide Pest Management Plan exemplifies Extension's continuing efforts to deliver up-to-date, technical information to Texas producers.

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All programs and information of the Texas Agricultural Experiment Station and The Texas Agricultural Extension Service are available to everyone without regard to race, color, religion, sex, age, or national origin.

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